Effects of restricted feed intake on finishing pigs weighing between 68 and 114 kilograms fed twice or 6 times daily[1]

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ABSTRACT: In a previous study with limit-fed gestating gilts, we observed that gilts fed 6 times/d had greater ADG than those fed the same amount over 2 feedings. To confirm these earlier responses, we used finishing pigs as a model in two 42-d trials and two 28-d trials to evaluate the effects of restricted feed intake and feeding frequency (2 vs. 6 times/d, floor fed) on pig performance between 68 and 114 kg. In all experiments, pigs (10/pen) were housed in 1.8 × 3.1 m pens with a half-solid, half-slatted concrete floor. Pigs were fed a corn- and soybean meal-based diet formulated to 1.15% standardized ileal digestible Lys and 3,294 kcal of ME/kg. In Exp. 1 to 3, energy and Lys were supplied to pigs according to NRC (1998) calculations to target an ADG of 0.80 kg. In Exp. 4, the diet was supplied to pigs to target an ADG of 0.80 kg (low feed intake) or 0.95 kg (high feed intake) to determine if the amount of energy above the maintenance requirement and feeding frequency affected pig performance. Pigs were fed by dropping similar amounts of feed onto the solid concrete floor either 2 (0700 or 1400 h) or 6 times (3 meals within 2 h at the morning and afternoon feedings) per day with an Accu-Drop Feed Dispenser (AP Systems, Assumption, IL). In Exp. 1 and 2, pigs fed 6 times daily had increased ($P < 0.02$) ADG and G:F compared with pigs fed 2 times per day. Greater feeding frequency increased ($P < 0.05$) the duration of time spent feeding and standing and reduced the lying time. In Exp. 3, a third treatment was included to determine whether the improvements in performance were due to decreased feed wastage. This treatment was designed to minimize feed wastage by dropping feed closer to the floor for pigs fed 2 times per day. Pigs fed 6 times daily had improved ($P < 0.05$) ADG and G:F compared with pigs in either treatment fed 2 times per day. No difference ($P > 0.05$) in performance was observed between pigs fed 2 times per day when feed was dropped from the feed drop or by the modified method. In Exp. 4, increasing the feeding frequency from 2 to 6 times per day improved ($P < 0.01$) ADG and G:F for pigs fed the low feed intake and tended to increase ($P < 0.06$) ADG and improved ($P < 0.05$) G:F for pigs fed the high feed intake. In limit-feeding situations, increasing the frequency of feeding from 2 to 6 times per day improved pig performance, which confirmed our earlier findings in gestating gilts.

Key words: feeding frequency, growth, pig, restricted intake

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INTRODUCTION

Sow longevity is the primary economic indicator of efficient piglet production. Most sow longevity research has concentrated on feed intake and backfat loss during lactation (Serenius et al., 2006). However, little information is available on the effect of gilt performance on longevity (Rozeboom et al., 1996). Current gilt development recommendations suggest that gilts reach their second estrus at a minimum BW of approximately 135 kg before they are eligible for breeding, and some producers and breeding stock companies also desire gilts to reach a minimum age (Young, 2004). In increased health situations, gilts may be past the 135 kg of BW target before they reach their second estrus or the minimum age set by the breeding stock supplier. Gilts that are too heavy at initial mating have reduced lifetime performance in the breeding herd (Amaral Filha et al., 2009). Ultimately, heavier gilts have an increased gestation maintenance requirement (NRC, 1998). This increase in physical size may dictate wider stall dimensions to maintain the welfare standard of stalls that do not obstruct sow movement (McGlone et al., 2004).

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Restricting feed intake to a moderate growth rate in developing gilts before they reach 135 kg may help prevent excessively heavy gilts. However, restricting feed intake during the growing phase is extremely difficult because most modern facilities are designed to use pens for developing replacement gilts. Previously, Schneider et al. (2007) observed that gilts fed 6 times daily during the first 42 d of gestation tended to have greater ADG than gilts fed 2 times daily; however, this response was not found in sows. Similar research has not been conducted with developing gilts or finishing pigs. The objective of this study was to determine whether increasing the number of meals from 2 to 6 per day would increase ADG in restricted-fed pigs in a group-housing environment.

MATERIALS AND METHODS

Procedures used in these experiments were approved by the Kansas State University Institutional Animal Care and Use Committee.

General

All experiments were conducted in a single room at the Kansas State University Swine Research and Teaching Center. Each pen was 1.8 × 3.1 m and had a half-solid (1.8 × 1.55 m), half-slatted floor with a deep pit. The facility was environmentally controlled with 1 curtain side to maintain pigs within their thermoneutral zone. Each pen was equipped with solid-side partitioning gates over the solid floor between pens to prevent feed transfer. Each pen had 1 nipple waterer to allow ad libitum access to water. The experimental diet was a corn and soybean meal diet formulated to 1.15% standardized ileal digestible Lys and 3,287 kcal of ME/kg (Table 1). If a pig was removed from the study for any reason, the pig BW and pen feed consumption to date were recorded and feed drops were adjusted to accommodate changes in the feeding calculation. No removals occurred in Exp. 1, 3, or 4. Six removals occurred in Exp. 2 (2 on twice-per-day feeding and 4 on 6 times-per-day feeding). Feed was measured and delivered with an Accu-Drop Feed Dispenser (Automated Production Systems, Assumption, IL) located approximately 1.8 m from the solid concrete floor where feed was consumed. There were 2 dispensers in each pen to provide the required feeding amount. Dispensers were located in the center at the back of the pen to allow all the feed to be dropped on the solid floor to minimize feed wastage. With the solid floor being 50% of the pen, the feeding area was 2.79 m^2 to provide space for all pigs to eat at the same time. In all trials, the genetics of pigs were PIC 1050 × 327.

Exp. 1 and 2

A total of 320 pigs (Exp. 1, initial BW = 67.3 kg, n = 160; Exp. 2, initial BW = 70.1 kg, n = 160) were used in a 42-d growth assay to determine the effects of feeding a restricted feed amount either 2 or 6 times per day on growth performance. Pigs were separated by sex and blocked by BW into 16 pens with 10 pigs each. There were 4 pens of barrows and 4 pens of gilts per treatment, for a total of 8 replications. Pigs were provided their daily feed allotment in 2 or 6 meals. In Exp. 1, pigs receiving 2 meals were fed at 0700 and 1530 h. Pigs fed 6 times per day were fed at 0700, 0730, 0800, 1530, 1600, and 1630 h. In Exp. 2, pigs receiving 2 meals were fed at 0700 and 1500 h. For pigs fed 6 times per day, meal timing was changed slightly to determine whether time between meals influenced the response found in Exp. 1. Pigs fed 6 times per day were fed at 0700, 0800, 0900, 1500, 1600, and 1700 h. All pigs were fed a restricted feed diet that was calculated according to NRC (1998) values to allow a BW gain of 620 g/d. To achieve this BW gain, pigs were assumed to have an average fat-free lean gain of 350 g/d as an input in the NRC (1998) model. The projected midpoint BW was used as the pig BW to determine maintenance requirements (106 kcal × $BW^{0.75}$). Dietary energy intake was altered to achieve the expected daily BW gain. Because energy

Table 1. Composition of the experimental diet used in Exp. 1 to 4 (as-fed basis)

Item	Amount
Ingredient, %	
Corn	63.14
Soybean meal (46.5% CP)	33.26
Monocalcium phosphate (21% P)	1.40
Limestone	1.25
NaCl	0.35
Trace mineral premix[1]	0.20
Vitamin premix[2]	0.15
L-Lys-HCl	0.15
L-Thr	0.05
DL-Met	0.05
Calculated analysis, %	
ME, kcal/kg	3,287
CP (N × 6.25)	21.00
Total Lys	1.29
Ca	0.87
Available P	0.37
Standardized ileal digestible AA, %	
Lys	1.15
Thr	0.74
Ile	0.79
Leu	1.66
Analyzed composition, %	
CP	21.05
Total Lys	1.19
Total Thr	0.82
Total Ile	1.33
Total Leu	0.84

[1]Premix provides potency amounts of the following nutrients per kilogram: Cu at 11 g, I at 198 mg, Fe at 110 g, Mn at 26 g, Se at 198 mg, and Zn at 110 g.

[2]Premix provides potency amounts of the following nutrients per kilogram: vitamin A at 4,400,000 IU, vitamin D at 660,000 IU, vitamin E at 17,6000 IU, vitamin K at 1,760 mg, vitamin B_{12} at 15 mg, niacin at 19,800 mg, pantothenic acid at 11,000 mg, and riboflavin at 3,300 mg.

intake was less than that required for 350 g/d of lean gain, the model predicted a carcass lean tissue gain of 250 g/d. In these experiments, the amount of feed given to a pen was determined every 14 d on the basis of the overall average BW of pigs. Pigs were weighed individually on d 0, 14, 28, and 42 to determine ADG, G:F, and CV for individual pig BW gain within the pen.

Exp. 3

A total of 150 pigs (initial BW = 70.8 kg) were used in a 28-d growth assay to determine the effects of feeding a restricted feed amount either 2 or 6 times per day on growth performance and whether feed wastage was the reason for the difference in performance found in Exp. 1 and 2. Pigs were assigned to 1 of 3 treatments with 15 pens of 10 pigs each. There were 5 replications per treatment. The 3 treatments were pigs fed 6 times daily, pigs fed 2 times daily, and pigs fed 2 times with a modified feeding system to attempt to limit feed wastage (termed "2-Modified"). Our theory was that a large amount of feed was being dropped onto the backs of the pigs, which increased feed wastage in pigs fed 2 times per day. The 2-Modified treatment consisted of using PVC piping and flex tubing to place the daily feed allotment directly on the concrete floor; in addition, 3.8 × 14.0 cm boards were attached in front of the partial slats. Pigs receiving 2 meals were fed at 0700 and 1500 h. Pigs fed 6 times per day were fed at 0700, 0800, 0900, 1500, 1600, and 1700 h. Similar to Exp. 1 and 2, all pigs were fed a restricted feed amount that was calculated according to NRC (1998) values to allow a gain of 620 g/d. In Exp. 3, the amount of feed given to a pen was determined every 14 d on the basis of the overall average BW of pigs. Pigs were weighed individually on d 0, 14, and 28 to determine ADG, G:F, and CV for individual pig BW gain within the pen.

Exp. 4

A total of 160 pigs (initial BW = 70.7 kg) were used in a 28-d growth assay to determine the effects of different feed intakes fed either 2 or 6 times per day on pig growth performance. Pigs were separated by sex and allotted randomly by BW to 16 pens of 10 pigs each. There were 4 replications per treatment. Feed intake amounts were based on NRC (1998) values to target an average growth rate of 620 g/d (low feed intake) or 730 g/d (high feed intake) to determine if the amount of energy above the maintenance requirement and feeding frequency had affected performance. The specific objective of Exp. 4 was determine if pigs fed 6 times per day with a diet that was closer to ad libitum intake would have a growth response similar to those fed 2 times per day. Pigs receiving 2 meals were fed at 0700 and 1500 h. Pigs fed 6 times per day were fed at 0700, 0800, 0900, 1500, 1600, and 1700 h. Pigs were weighed individually every 14 d to determine ADG, G:F, and CV for individual pig BW gain within the pen.

Behavioral Measures

Pig behaviors were recorded continuously for 24 h with a digital video recorder on d 3 to 4, d 15 to 16, d 29 to 30, and d 40 to 41 of Exp. 1 and 2. Individual pigs within pens were marked to allow behavior for each pig to be monitored. Behaviors were observed by using the Observer 5.1 behavior program (Noldus, Leesburg, VA), which allowed the frequency and duration of behaviors to be averaged for the 24-h periods. A single observer monitored all the videos for consistency. Behavior videos were blocked by time, and pens were selected randomly for observations. Two pens per treatment were monitored during each time period. Behaviors were similar across time periods and, thus, were summarized for overall treatment effects. The behaviors were adapted from Dailey and McGlone (1997) and were recorded as time spent drinking, eating, oral-nasal-facial, sitting, standing, lying, or antagonistic (behavior indicative of social conflict). The total active behaviors were calculated as the sum of all behaviors other than lying. Standing behavior was defined as when the animal adopted an upright position with all legs supporting the body. Lying was defined as involving contact of the body with the ground and the legs not supporting the body. Sitting behavior was defined as when the hindquarter portion of the body was in contact with the ground and the front legs were supporting the body. Feeding behavior was defined as when the pig was standing with its head down on the solid concrete floor. Drinking behavior was defined as when pigs pressed their nose against the nipple waterer. Antagonistic was defined as physical encounters between at least 2 pigs. Oral-nasal-facial behavior was defined as belly-nosing, rubbing, sniffing, or licking of their pen-mates.

Statistical Analysis

Data from all experiments were analyzed as a randomized complete block design using the MIXED procedure (SAS Inst. Inc., Cary, NC), with pen as the experimental unit. The growth assay model included the fixed effect of treatment and the random effect of block. In Exp. 4, treatments were organized as a 2 × 2 factorial and analyzed for the main effects of feed intake amount and feeding frequency and the interaction of feed intake amount × feeding frequency. No significant effect ($P > 0.20$) of sex was observed in any of the experiments; therefore, all performance data within a treatment were pooled. Behavioral data were averaged over the 24-h period and were represented as a percentage of behavioral actions throughout the recorded period. Behavior data that were not normally distributed were logarithmically transformed before analysis. The model for the behavioral observations included the fixed effect of treatment and the random effects of pen and block. Least squares means were calculated for each independent variable and evaluated with the PDIFF option of

Table 2. Effect of feeding frequency of an energy-restricted diet on the performance of finishing pigs (Exp. 1)[1]

	Frequency of feeding per day			
d 0 to 42[2]	2[3]	6[4]	SEM	P-value
ADG, g	606	683	15.74	<0.01
ADFI, g	1,677	1,677	0.62	<0.77
G:F	0.36	0.41	0.01	<0.01
CV of BW gain, %	4.62	4.52	0.23	<0.83

[1]Each value is the mean of 8 replications with 10 pigs (initially 66.9 kg) per pen.

[2]Feed drops were adjusted every 14 d on the basis of the average BW of pigs.

[3]Received feed at 0700 and 1530 h.

[4]Received feed at 0700, 0730, 0800, 1530, 1600, and 1630 h.

SAS. If interactions were significant in Exp. 4, PDIFF was used to separate individual treatment means. Statistical significance and tendencies were set at $P \leq 0.05$ and $P < 0.10$ for all statistical tests.

RESULTS

Exp. 1

Overall (d 0 to 42), pigs fed 6 times vs. 2 times per day had increased ($P < 0.01$; Table 2) ADG and G:F. As expected, ADFI was not different ($P = 0.77$) between the treatments because similar amounts of feed were provided in both treatments. Feeding frequency did not influence ($P = 0.83$) the CV for individual pig BW gain within the pen. Increasing the feeding frequency increased ($P < 0.03$; Table 3) the time spent feeding, standing ($P < 0.01$), and oral-nasal-facial ($P < 0.03$) and reduced ($P < 0.01$) the time spent lying. This resulted in an overall increase ($P < 0.01$) in activity.

Exp. 2

Overall (d 0 to 42), pigs fed 6 times vs. 2 times per day had increased ($P < 0.02$; Table 4) ADG and G:F. As expected, ADFI was not different ($P > 0.91$) between treatments because similar amounts of feed were provided in both treatments. Feeding frequency did not influence ($P = 0.45$) the CV for individual pig BW gain within the pen. Increasing the feeding frequency increased ($P < 0.01$; Table 5) the time spent feeding and standing ($P < 0.01$) and reduced the time spent lying ($P < 0.01$). This resulted in an overall increase ($P < 0.01$) in activity.

Exp. 3

Overall (d 0 to 28), pigs fed 6 times per day had increased ($P < 0.05$; Table 6) ADG and G:F compared with pigs fed twice a day from either the modified feeders or the feed drops. As expected, ADFI was not different ($P = 0.57$) between treatments because similar amounts of feed were provided in all treatments. Feeding frequency did not influence ($P = 0.36$) the CV for individual pig BW gain within the pen.

Exp. 4

Overall (d 0 to 28), there tended to be a feed intake amount × feeding frequency interaction for ADG ($P <$

Table 3. Duration of behaviors, expressed as a percentage of time over 24 h (Exp. 1)[1,2]

	Frequency of feeding per day			
Behavior	2[3]	6[4]	SEM	P-value
Lying	87.78	85.65	0.19	<0.01
Total active behavior[5]	12.22	14.35	0.19	<0.01
Agonistic	0.26	0.28	0.06	<0.51
Oral-nasal-facial	1.3	1.65	0.09	<0.03
Standing	4.7	5.7	0.12	<0.01
Sitting	0.62	0.67	0.06	<0.44
Drinking	0.31	0.33	0.03	<0.40
Feeding	5.03	5.73	0.16	<0.03

[1]Each value is the mean of 8 replications with 10 pigs (initially 66.9 kg) per pen.

[2]Values for the behavior observations were averaged over a 24-h period for a combination of 4 total days per treatment.

[3]Received feed at 0700 and 1530 h.

[4]Received feed at 0700, 0730, 0800, 1530, 1600, and 1630 h.

[5]Total active behavior is the sum of all behaviors other than lying.

Table 4. Effect of feeding frequency of an energy-restricted diet on the performance of finishing pigs (Exp. 2)[1]

	Frequency of feeding per day			
d 0 to 42[2]	2[3]	6[4]	SEM	*P*-value
ADG, g	504	623	28.52	<0.02
ADFI, g	1,728	1,728	0.54	<0.91
G:F	0.29	0.36	0.02	<0.02
CV of BW gain, %	5.18	4.77	0.37	<0.45

[1]Each value is the mean of 8 replications with 10 pigs (initially 70.1 kg) per pen.

[2]Feed drops were adjusted every 14 d on the basis of the average BW of pigs.

[3]Received feed at 0700 and 1500 h.

[4]Received feed at 0700, 0800, 0900, 1500, 1600, and 1700 h.

0.08) and G:F ($P < 0.02$; Table 7). The interactions occurred because increasing the feeding frequency from 2 to 6 times per day increased ADG and G:F to a greater extent for pigs on the low feed intake than for pigs on the high feed intake. Compared with pigs fed 2 times per day, pigs fed 6 times per day at the low feed intake had increased ($P < 0.01$) ADG, and pigs fed 6 times per day at the high feed intake had a tendency for increased ($P < 0.06$) ADG. Pigs fed either the high or low feed intake 6 times per day had improved ($P < 0.05$) G:F compared with pigs fed 2 times per day. Increasing the feed intake amount increased ($P < 0.01$) ADFI and reduced ($P < 0.05$) the CV for individual pig BW. Increasing the feeding frequency tended to reduce ($P < 0.10$) the CV for individual pig BW. Feeding frequency did not influence ($P = 0.63$) ADFI. This was expected because similar amounts of feed were provided in all treatments.

DISCUSSION

Even though pigs in these experiments were fed an equal amount of feed based on average BW to attain a specific growth rate, feeding 6 times daily increased ADG and improved feed efficiency compared with feeding 2 times daily. This result may have been due to improved nutrient digestibility (de Haer and de Vries, 1993b) and a change in basal metabolism (Sharma et al., 1973) associated with an increase in feeding frequency. Increasing feeding frequency has been shown to increase the flow of digestive enzyme production in the small intestine (Ruckenbusch and Bueno, 1976; Sisson and Jones, 1991; van Leeuwen et al., 1997). It has also been suggested that increasing the feeding frequency increases pancreatic secretions and has a positive relationship with digestibility (Hee et al., 1988; de Haer and de Vries, 1993a). Botermans et al. (2000) provided some evidence of this, whereby they observed that increasing the number of meals (1 vs. 12) increased protein output, chymotrypsin, and lipase activity. In addition, this increase in exocrine pancreatic secretion was found to be independent of the amount of feed consumed (Botermans and Pierzynowski, 1999).

Another possible explanation for the increased performance is a response called the second-meal phenomenon (Jenkins et al., 1980). This phenomenon is thought to improve carbohydrate tolerance and reduce the insulin response by spreading the nutrient load over a longer period of time. In addition, the closeness of 1 meal to the next determines the glycemic response and

Table 5. Duration of behaviors expressed as a percentage of time over 24 h (Exp. 2)[1,2]

	Frequency of feeding per day			
Behavior	2[3]	6[4]	SEM	*P*-value
Lying	87.54	85.12	0.08	<0.01
Total active[5]	12.46	14.88	0.08	<0.01
Agonistic	0.29	0.31	0.03	<0.60
Oral-nasal-facial	1.38	1.50	0.06	<0.15
Standing	5.15	6.08	0.13	<0.01
Sitting	0.61	0.63	0.03	<0.55
Drinking	0.31	0.32	0.01	<0.45
Feeding	4.73	6.05	0.15	<0.01

[1]Each value is the mean of 8 replications with 10 pigs (initially 66.9 kg) per pen.

[2]Values for the behavior observations were averaged over a 24-h period for a combination of 4 total days per treatment.

[3]Received feed at 0700 and 1530 h.

[4]Received feed at 0700, 0730, 0800, 1530, 1600, and 1630 h.

[5]Total active behavior is the sum of all active behaviors. Lying behavior was determined by subtracting active behavior from 100.

Table 6. Effect of feeding frequency of an energy-restricted diet on the performance of finishing pigs (Exp. 3)[1]

	Frequency of feeding per day			
d 0 to 28[2]	2[3]	2-Modified[3]	6[4]	SEM
ADG, g	518[a]	509[a]	608[b]	26.56
ADFI, g	1,658	1,657	1,657	1.99
G:F	0.31[a]	0.31[a]	0.37[b]	0.02
CV of BW gain, %	4.46	4.01	4.75	0.55

[a,b]Within a row, means without a common superscript differ ($P < 0.05$).

[1]Each value is the mean of 8 replications with 10 pigs (initially 70.8 kg) per pen.

[2]Feed drops were adjusted every 14 d on the basis of the average BW of pigs.

[3]Received feed at 0700 and 1500 h. Pens fed the 2-modified treatment were fed twice daily, and feed was delivered directly onto the concrete floor.

[4]Received feed at 0700, 0800, 0900, 1500, 1600, and 1700 h.

potentially eliminates extreme larger and smaller glycemic peaks. The result is a smoother, more controlled response, which creates more efficient utilization. This hypothesis is used in human health studies that attempt to decrease the occurrence of diabetes by manipulating the frequency of meals. Lundin et al. (2004) showed that diabetic patients improve their glucose tolerance when consuming an isocaloric diet over 10 vs. 3 meals. Furthermore, studies involving human patients have shown that increased meal frequency reduced total cholesterol, low-density lipoprotein cholesterol, and serum FFA (Cohn, 1964; Jenkins et al., 1989; Wolever, 1990).

The observed effect of increasing feeding frequency on ADG and G:F was consistent in all our experiments. We hypothesized that the ADG response in Exp. 1 and 2 was due to feed wastage in pigs fed 2 times daily and that the wastage was a result of feed falling directly onto the backs of the pigs during feeding. Therefore, the modified treatment in Exp. 3 delivered feed directly to the floor. However, the growth performance of pigs fed 6 or 2 times daily in Exp. 3 mimicked the response in Exp. 1 and 2. Thus, we concluded that the ADG response was not due to differences in feed wastage between treatments. This was further confirmed by the consistent improvement in G:F, which indicated improved nutrient utilization.

These results were similar to those of Sharma et al. (1973), who revealed that frequency of feeding influenced energy utilization. In that study, pigs fed multiple times had greater maintenance requirements but also were more efficient converters of the ME available above the maintenance requirement for tissue deposition. On the other hand, work by van Leeuwen et al. (1997) and Friend and Cunningham (1964) did not demonstrate differences in digestibility or performance between pigs fed the same total amount of feed in large meals or several small meals. Previously, Schneider et al. (2007) tested the same feeding regimen used in this study on gestating gilts and sows. In that study, feeding 2 or 6 times daily did not affect the growth performance of gestating sows, but there was an increase in ADG for gestating gilts from d 0 to 42 of gestation. The treatment effect in the present experiments and in the first period of gestating gilts may be related to the availability of energy above maintenance requirements.

After examining these results, we questioned whether the amount of energy above the maintenance requirement affected performance. In Exp. 4, energy and Lys were supplied to pigs on the basis of NRC (1998) mod-

Table 7. Effect of feeding frequency of an energy-restricted diet on the performance of finishing pigs (Exp. 4)[1]

	Frequency of feeding per day					*P*-value		
	Low feed intake[3]		High feed intake[4]					
d 0 to 28[2]	2[5]	6[6]	2[5]	6[6]	SEM	Feeding level	Feeding frequency	Feeding level × frequency
ADG, g	466	633	635	709	44.76	0.01	0.01	0.08
ADFI, g	1,610	1,610	2,048	2,047	1.25	0.01	0.63	0.26
G:F	0.29	0.39	0.31	0.35	0.02	0.33	0.01	0.02
CV of gain, %	4.62	4.24	4.12	3.53	0.27	0.05	0.10	0.70

[1]Each value is the mean of 4 replications with 10 pigs (initially 70.7 kg) per pen.

[2]Feed drops were adjusted every 14 d on the basis of the average BW of pigs.

[3]Pigs were fed according to NRC (1998) values to gain 620 g/d.

[4]Pigs were fed according to NRC (1998) values to gain 730 g/d.

[5]Received feed at 0700 and 1500 h.

[6]Received feed at 0700, 0800, 0900, 1500, 1600, and 1700 h.

els to target an average growth rate of 620 g/d (low feed intake) or 730 g/d (high feed intake) to determine if pigs fed 6 times per day on a diet that was closer to ad libitum intake (low feed intake = 1.9 times above maintenance; high feed intake = 2.3 times above maintenance) would have a growth requirement similar to those fed 2 times per day. Pigs fed both feed intake amounts had improved ADG and G:F as feeding frequency increased from 2 to 6 times daily. However, pigs fed the low feed intake amount had larger improvements than those fed the high feed intake amount. These data suggest that the amount fed relative to maintenance influences the response to the number of meals fed, but does not explain all the difference.

Discrepancies were observed in the predicted growth rate vs. the actual growth response. For Exp. 2, 3, and 4, the ADG of pigs fed 6 times per day was closer to the modeled projections than the growth rate of pigs fed 2 times per day. These results would suggest that pigs fed 2 times per day had an impaired growth rate relative to modeled expectations. The differences in the ADG responses in our growth assays compared with those predicted by the NRC (1998) calculations may be due to environment, genetics, or inaccuracies in the NRC (1998) equations. Inaccuracies in ADG calculated using NRC (1998) models may be due to an underestimated maintenance requirement [i.e., feed intake was based on the initial period (d 0 or the 14-d period) BW for maintenance], an overestimation of fat-free lean gain when limiting energy intake, or both. For example, if the maintenance requirements of Noblet et al. (1999) were used instead of NRC, projected BW gain would be approximately 66 g/d less in each experiment. If activity was greater for pigs fed 2 times per day than those fed 6 times per day, it may have explained some of the differences in growth rate because more energy would have been needed for activity; however, pigs fed 2 times per day were actually less active than those fed 6 times per day.

Behavior observations revealed that increasing the feeding frequency from 2 to 6 times per day increased active behavior and decreased the amount of time spent lying. Previous studies with growing-finishing pigs fed a liquid diet yielded similar results when feeding frequency was increased from 2 to 3 times per day (Kracht et al., 1982) and from 3 to 9 times per day (Hessel et al., 2006). In the present study, pigs fed 6 times per day spent more time feeding than pigs fed 2 times per day. This is similar to results from Hessel et al. (2006), who reported that pigs fed 9 times per day spent more time feeding than pigs fed 3 times per day. However, Hulbert and McGlone (2006) did not report a difference in the duration of feeding behaviors in sows fed by either a drop or trickle feeding method. The greater activity did not appear to greatly influence pig performance because pigs fed 6 times per day had greater activity and greater performance than those fed 2 times per day.

According to Baxter (1986), 90% of all aggressive interactions between pigs occur during feeding as a direct result of competition. In the present study, feeding frequency did not influence time budgets of agonistic behavior. However, Hessel et al. (2006) found an increase in agonistic behavior for pigs fed 9 times daily vs. pigs fed 3 times daily in the growing-finishing period. In addition, pigs fed 9 times per day were more likely to have a greater injury score for the caudal part of their body. Behavior differences between our study and the study by Hessel et al. (2006) may be due to diet and pen effects. Hessel et al. (2006) restrictively fed pigs a liquid whey diet in a trough, whereas pigs in the current experiments were fed a corn- and soybean meal-based diet on a solid concrete floor. Because pigs in both treatments were housed in the same room, the behavior of pigs fed 6 times per day may have influenced the behavior of pigs fed 2 times per day to lessen potential treatment differences.

Increasing feeding frequency from 2 to 6 times daily increased ADG and feed efficiency of floor-fed, group-housed finishing pigs, which confirmed our earlier findings in gestating gilts. The observed effects of feeding frequency on growth were true for pigs fed energy restricted or closer to ad libitum intake. The improvements in feed efficiency were not associated with differences in feed wastage, but may have been due to improvements in nutrient utilization or changes in basal metabolism associated with an increase in feeding frequency. Increasing the feeding frequency did not influence time budgets of agonistic behavior of finishing pigs, but increased active behavior and decreased the amount of time spent lying. Reducing the number of daily feedings for restricted-fed finishing pigs may be a strategy for managing BW gain when attempting to limit BW gain, such as with developing gilts.

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