EFFECT OF RESTRICTED FEED INTAKE ON FINISHING PIGS WEIGHING BETWEEN 150 AND 250 lb FED TWICE OR SIX TIMES DAILY

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Summary

Two 42-d trials and two 28-d trials were conducted to evaluate the effects of restricted feed intake and feeding frequency (2 or 6 times daily) on the performance of pigs weighing between 150 to 250 lb (initially 148 lb in Exp. 1; 155 lb in Exp. 2; 156 lb in Exp. 3; and 156 lb in Exp. 4). In all experiments, pigs were housed in 6 × 10 ft pens with half-solid concrete and half-slatted flooring and with one nipple waterer. Pigs were fed a corn-soybean meal-based diet formulated to 1.15% TID lysine and 1,491 kcal of ME/lb.

In Exp. 1 to 3, energy and lysine were supplied to pigs to target an average growth rate of 1.75 lb/d based on NRC (1998) values. In Exp. 4, the diet was supplied to pigs to target growth rates of 1.75 lb/d (low feed intake) or 2.1 lb/d (high feed intake) based on NRC (1998) values to determine if the amount of energy above maintenance and feeding frequency has an effect on performance. Pigs were fed by dropping similar daily amounts of feed, either 2 (0700 and 1400) or 6 times (3 meals within 2 h at AM and PM feedings) per day, by an Accu-Drop Feed Dispenser® on the solid concrete flooring.

In Exp. 1 and 2, increasing the feeding frequency of pigs fed a restricted diet from 2 to 6 times per day improved ($P<0.02$) ADG and F/G. Increasing the feeding frequency increased ($P<0.05$) the duration of time spent feeding and standing, and reduced lying time. In Exp. 3, a third treatment was included in addition to those used in Exp. 1 and 2 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 in pigs fed 2 times per day. Like Exp. 1 and 2, pigs fed 6 times per day had improved ($P<0.05$) ADG and F/G compared to either treatment fed 2 times per day. There was no difference ($P>0.05$) in performance 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 feeding periods improved ($P<0.01$) ADG and F/G for pigs fed a low level of feed intake and tended to increase ($P<0.06$) ADG and improve ($P<0.05$) F/G for pigs fed a high level of feed intake. In conclusion, these studies indicate that increasing the frequency of feeding from 2 to 6 times a day improves pig performance compared with feeding 2 times per day.

(Key words: feed management, restricted intake.)

Introduction

In last year's Swine Industry Day Report of Progress, we tested whether increasing the feeding frequency would improve the welfare

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and/or reduce the variation of weight gain in group-housed sows. Results from this trial showed an increase in ADG for gilts fed six times versus two times a day during the first 42 d of gestation; however, this response was not found in sows. Because of the difference seen in performance between feeding frequencies we wanted to further evaluate the response. Therefore, the objective of this study was to determine the effects of restricting feed intake of pigs fed either 2 or 6 times per day in a group housed environment.

Experimental Procedures

All experiments were conducted at the Kansas State University Swine Research and Teaching Center. Each pen was 6 × 10 ft and contained half solid and half slatted flooring with a deep pit and one curtain side (Figure 1). Each pen was equipped with solid side partitioning gates over the solid flooring between pens to prevent feed transfer. In each pen there was one nipple waterer to allow *ad libitum* access to water. The experimental diet was a corn-soybean meal diet formulated to 1.15% true ileal digestible lysine and 1,490 ME kcal/lb (Table 1). If a pig was removed from the study for any reason, the pig weight and pen feed consumption to date was recorded and feed drops were adjusted to accommodate changes in the feeding calculation. Feed was measured and delivered using an Accu-Drop Feed Dispenser® (Automated Production Systems, Assumption, IL) which was located approximately 6 ft from the solid concrete floor where the feed was consumed.

Experiments 1 and 2. A total of 320 pigs (Exp. 1, initial wt = 148 lb, n = 160; Exp. 2 initial wt = 155 lb, n = 160) were used in a 42-d growth assay to determine the effects of feeding a restricted feed level either two or six times per day on growth performance. Pigs were separated by sex and blocked by body weight to 16 pens of 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 two or six meals. In Exp. 1, Pigs receiving two meals were fed at 0700 and 1530 hr. Pigs fed six times per day were fed at 0700, 0730, 0800, 1530, 1600, and 1630 hr. In Exp. 2, Pigs receiving two meals were fed at 0700 and 1500 hr. Pigs fed six times per day were fed

Table 1. Composition of Experimental Diet[a]

Item	Diet, %
Corn	63.14
Soybean meal (46.5% CP)	33.26
Monocalcium P (21% P, 18% Ca)	1.40
Limestone	1.25
Salt	0.35
Trace mineral premix	0.20
Vitamin premix	0.15
L-lysine HCL	0.15
L-threonine	0.05
DL-methionine	0.05
Total	100.00
Calculated analysis	
ME, kcal/lb	1,491
CP, %	21.0
Total lysine, %	1.29
TID amino acids, %	
Lysine	1.15
Threonine	0.74
Isoleucine	0.79
Leucine	1.66
Ca	0.87
Available P	0.37
Analyzed composition, %	
CP	21.05
Total lysine	1.19
Total threonine	0.82
Total isoleucine	1.33
Total leucine	0.84

[a]This diet, fed in meal form, was used in all experiments.

at 0700, 0800, 0900, 1500, 1600, and 1700 hr. All pigs were fed a restricted feed level that was calculated to allow a gain of 0.80 kg/day based on NRC (1998) values. In these experiments the amount of feed given to a pen was determined every 14 d based on combined pen weight. Pigs were weighed individually on d 0, 14, 28, and 42 to determine ADG, F/G, and CV for individual pig weight gain within the pen.

Experiment 3. A total of 150 pigs (initial wt = 156) were used in a 28-d growth assay to determine the effects of feeding a restricted feed level either two or six times per day on growth performance and to determine whether feed wastage was the reason for the difference in performance found in Exp. 1 and 2. Pigs were assigned to one of three treatments with 15 pens of 10 pigs each. The treatments consisted of feeding times with pigs fed six times daily, pigs fed twice daily, and pigs fed twice daily with an modified feeding system to attempt to limit feed wastage (2 Modified; Figure 2). The modified treatment consisted of using PVC piping and flex-tubing to place the daily feeding allotment on the concrete flooring, also boards were attached in front of the partial slats to prevent feed from entering the partial slats. Pigs were provided their daily feed allotment in two or six meals. Pigs receiving two meals were fed at 0700 and 1500 h. Pigs fed six times per day were fed at 0700, 0800, 0900, 1500, 1600, and 1700 h. All pigs were fed a restricted feed level that was calculated to allow a gain of 1.75 lb/day based on NRC (1998) values. In these experiments the amount of feed given to a pen was determined every 14 d based on combined pen weight. Pigs were weighed individually on d 0, 14, and 28 to determine ADG, F/G, and CV for individual pig weight gain within the pen.

Experiment 4. A total of 160 pigs (initial BW = 156 lb) were used in a 28-d growth assay to determine the effects of feeding different levels of feed intake either two or six times per day on pig growth performance. The pigs were separated by sex and randomly allotted by weight to 16 pens of 10 pigs each. Energy and lysine were supplied to pigs to target an average growth rate of 1.75 lb/day (low feed intake level) or 2.1 lb/day (high feed intake level) based on NRC (1998) values to determine if the amount of energy above maintenance and feeding frequency has an effect on performance. Pigs receiving two meals were fed at 0700 and 1500 h. Pigs fed six times per day had a greater interval between meals within the morning and afternoon with feedings at 0700, 0800, 0900, 1500, 1600, and 1700 h. Pigs were weighed individually every 14 d to determine ADG, F/G, and CV for individual pig weight gain within the pen.

Behavioral Measures. Behaviors were recorded continuously for 24 h using a digital video recorder on d 3 to 4, 15 to 16, 29 to 30, and 40 to 41 of Exp. 1 and 2. Behaviors were observed using the Observer 5.1 behavior program which allowed the frequency and duration of behaviors to be averaged for the 24 h periods. Behavior videos were blocked by time, and pens were randomly selected for observations. The behaviors were adapted from work at Texas Tech University and were recorded as time spent drinking, eating, oral-nasal-facial (ONF), sitting, standing, lying, or antagonistic (behavior indicative of social conflict). The total active behaviors were calculated by subtracting lying behavior from the sum of all behaviors.

Standing behavior was defined as having taken place when the animal adopted an upright position with all legs supporting the body. Lying was defined to involve 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 support of body weight by front legs. Feeding behavior was when the pig was standing and 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 two pigs. Oral-nasal-facial behavior was defined as belly-nosing, rubbing, sniffing, or licking of their pen mates.

Statistical Analysis. The data from all experiments were analyzed as a randomized complete block design with pen as the experimental unit. There was no significant effect of sex in any of the experiments; therefore, all performance data within a treatment will be pooled. The behavioral data was averaged over the 24 h period and represented as a percent of behavioral actions throughout the recorded period. The model for the behavioral observations included the fixed effect of treatment and the random effect of pen and block. Analysis of variance was performed by using the MIXED procedure of SAS.

Results

Experiment 1. Overall (d 0 to 42), pigs fed 6 times versus 2 times a day had increased ($P<0.01$; Table 2) ADG and improved ($P<0.01$) F/G. As expected, ADFI was not different ($P=0.77$) due to the fact that similar amounts of feed were provided to both treatments. The CV for individual pig weight gain within the pen was not ($P=0.83$) influenced by feeding frequency. Increasing the feeding frequency increased the duration of time spent feeding ($P<0.03$; Table 3), standing ($P<0.01$), ONF ($P<0.03$), and reduced the time spent lying ($P<0.01$). This resulted in an overall increase in activity level ($P<0.01$).

Experiment 2. Overall (d 0 to 42), pigs fed 6 times versus 2 times a day had improved ($P<0.02$; Table 4) ADG and ($P<0.02$) F/G. Average daily feed intake was not influenced ($P=0.91$) as expected because similar amounts of feed were given to both treatments. The CV for individual pig weight gain within the pen was not influenced ($P=0.45$) by treatments. Increasing the feeding frequency increased the duration of time spent feeding ($P<0.01$; Table 5), standing ($P<0.01$), and reduced the time spent lying ($P<0.01$). This resulted in an overall increase in activity level ($P<0.01$).

Experiment 3. Overall (d 0 to 28), pigs fed 6 times a day had improved ($P<0.05$; Table 6) ADG and F/G over pigs fed twice a day from either the modified feeders and directly from the feed drops. Average daily feed intake was not influenced ($P = 0.57$) as expected because similar amounts of feed were given to all treatments. The CV for individual pig weight gain within the pen was not influenced ($P = 0.36$) by treatments.

Experiment 4. There were no interactions between feed intake level and feeding frequency for any response criteria. Overall (d 0 to 28), pigs fed the low feed intake level had increased ($P<0.01$; Table 7) ADG while those fed the high feed intake level had a tendency for increased ($P<0.06$) ADG when fed 6 times per day versus being fed 2 times per day. Pigs fed both high and low feed intake levels had improved ($P<0.05$) F/G when fed 6 times per day versus being fed 2 times per day. Average daily feed intake was not influenced by feeding frequency for pigs fed the high feed intake level ($P = 0.26$) or low feed intake level ($P = 0.63$). This was expected because similar amounts of feed were given to both treatments. The CV for individual pig weight gain within the pen was not influenced by feeding frequency for the pigs fed the high feed intake level ($P=0.15$) or low feed intake level ($P=0.35$) treatments.

Discussion

In these experiments, feeding six times increased ADG and improved feed efficiency versus pigs fed twice a day, even though the pigs were fed an equal amount of feed based

on average weight to attain a specific growth pattern. Other researchers have shown that feeding multiple times per day can improve nutrient digestibility. Increasing feeding frequency has been shown to increase the flow of digestive enzyme production in the small intestine.

Another possible explanation to the improved performance is a response called the second-meal phenomenon. This phenomenon is thought to improve carbohydrate tolerance and reduce the insulin response by spreading the nutrient load over a longer period of time. Furthermore, the closeness of one meal to the next determined the glycemic response and potentially eliminates the extreme high and low glycemic peaks. The result is a smoother more controlled response, thus creating more efficient tissue utilization. This hypothesis is used in human health studies that attempt to decrease the occurrence of diabetes by manipulating the frequency of meals. Diabetic patients improved their glucose tolerance when consuming an isocaloric diet over 10 meals versus three meals.

Regardless of the response method, in all studies increasing the feeding frequency from twice to six times a day increased ADG and improved F/G. Feed wastage was hypothesized to be responsible for the ADG response in Exp. 1 and 2. This was due to the potential wastage of feed that falls directly onto the pigs during feeding. Therefore, the modified treatment in Exp. 3 delivered feed directly to the floor, thus prevent feed from dropping directly onto the pig. However, the growth performance of pigs fed six or two times per day mimicked the response found in Exp. 1 and 2. Thus, it was concluded that the ADG response was not due to differences in feed wastage between treatments. This is further confirmed with the consistent improvement in F/G, indicating improved nutrient utilization.

Previous data on feeding frequency for finishing pigs is limited. One study found that pigs fed multiple times had higher maintenance requirements, but were also more efficient converters of the available ME taken above maintenance for tissue deposition. On the other hand, other researchers 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, we tested the same feeding regimen in gestating gilts and sows. There was no difference in growth performance for gestating sows, but there was an increase in ADG for gestating gilts in the first period measured (d 0 to 42). The reason for the treatment effect in the present experiments and in the first period of gestating gilts may be related to the amount of energy available above maintenance requirements. After examining these results a question arose concerning the amount of energy above maintenance and its effects on performance.

In Exp. 4, energy and lysine were supplied to pigs to target an average growth rate of 1.75 lb/day (low feed intake) or 2.1 lb/day (high feed intake) based on NRC (1998) values. The purpose of these dietary energy levels was to determine if similar growth response would be seen in pigs fed six times a day on a diet that was closer to *ad libitum* intake (low feed intake level = 2.1 times above maintenance; high feed intake level = 2.7 times above maintenance). We found improvements in ADG and F/G for both feed intake levels as feeding frequency increased from 2 to 6 times daily. However, those fed the lower feed intake level had larger improvements than those fed the higher feed intake level.

An area of concern with the present studies may be related to the discrepancies in the predicted growth rate versus the actual growth response. In Exp. 1, 2, and 3, all pigs were fed to gain 1.75 lb/d using the NRC (1998) calculations. However, the ADG responses in

our growth assays were under those predicted by the NRC (1998) calculations and may be due to environment, genetics, or inaccuracies in the NRC (1998) equations.

Results of the observation of behavior revealed that increasing the feeding frequency from 2 to 6 times per day increased active behavior (12.2 to 12.5% vs. 14.3 to 14.9%, respectively) and decreased the amount of time spent lying. Similar results were found by others when comparing an increase in feeding frequency of growing-finishing pigs fed a liquid diet when pigs were fed 2 vs. 3 times per day and when pigs were fed 3 vs. 9 times per day. The amount of time spent feeding was increased for pigs fed 6 times a day versus pigs fed 2 times a day. This also was similar to the results of others where pigs fed 9 times per day spent more time feeding than pigs fed 3 times per day. Almost 90% of all aggressive interactions between pigs occur during feeding as a direct result of competition. Time budgets of agonistic behavior were not influenced by feeding frequency in our study.

Figure 1. Pen Design for Pigs fed 2 or 6 Times per Day in All Experiments.

Figure 2. Picture Represents the Modified Treatment that Delivered Feed Directly onto the Concrete Flooring (Exp. 3).

Table 2. Effect of Feeding Frequency on Energy Restricted Diet on Performance of Finishing Pigs (Exp. 1)[a]

	Frequency of Feeding per Day			
Item	2	6	SE	*P*-value (*P* <)
ADG, lb	1.34	1.51	0.035	0.01
ADFI, lb	3.70	3.70	0.001	0.77
F/G	2.78	2.44	0.061	0.01
CV of gain, %	4.62	4.52	0.23	0.83

[a]Each value is the mean of eight replications with 10 pigs (initially 148 lb) per pen. Pens that were fed twice daily received feed at 0700 and 1530 h; Pens that were fed six times a day received feed at 0700, 0730, 0800, 1530, 1600, and 1630 h, respectively. Feed drops were adjusted every 14 d based on the average weight of pigs.

Table 3. The Duration of Behaviors Expressed as a Percentage of Time over 24 h (Exp. 1)[a]

	Frequency of Feeding per Day			
Behavior	2	6	SE	*P*-value (*P* <)
Agonistic	0.26	0.28	0.06	0.51
Active	12.20	14.35	0.19	0.01
Oral-nasal-facial	1.30	1.65	0.09	0.03
Lie	87.80	85.65	0.19	0.01
Stand	4.70	5.70	0.12	0.01
Sit	0.62	0.67	0.06	0.44
Drink	0.31	0.33	0.03	0.40
Feed	5.03	5.73	0.16	0.03

[a]Values for the behavior observations were averaged over a 24 h period for a combination of 4 total days per treatment. Active behavior was determined by subtracting lying behavior from the sum of all behavior

Table 4. Effect of Feeding Frequency on Energy Restricted Diet on Performance of Finishing Pigs (Exp. 2)[a]

	Frequency of Feeding per Day			
Item	2	6	SE	*P*-value (*P* <)
ADG, lb	1.11	1.37	0.06	0.02
ADFI, lb	3.81	3.81	0.01	0.91
F/G	3.45	2.78	0.16	0.02
CV of gain, %	5.18	4.77	0.37	0.45

[a]Each value is the mean of eight replications with 10 pigs (initially 155 lb) per pen. Pens that were fed twice daily received feed at 0700 and 1500 h. Pens that were fed six times a day received feed at 0700, 0800, 0900, 1500, 1600, and 1700 h, respectively. Feed drops were adjusted every 14 d based on the average weight of pigs.

Table 5. The Duration of Behaviors Expressed as a Percentage of Time over 24 h (Exp. 2)[a]

	Frequency of Feeding per Day			
Behavior	2	6	SE	*P*-value (*P* <)
Agonistic	0.29	0.31	0.03	0.60
Active	12.46	14.88	0.08	0.01
Oral-nasal-facial	1.38	1.50	0.06	0.15
Lie	87.55	85.12	0.08	0.01
Stand	5.15	6.08	0.13	0.01
Sit	0.61	0.63	0.03	0.55
Drink	0.31	0.32	0.01	0.45
Feed	4.73	6.05	0.15	0.01

[a]Values for the behavior observations were averaged over a 24 h period for a combination of 4 total days per treatment. Active behavior was determined by subtracting lying behavior from the sum of all behavior.

Table 6. Effect of Feeding Frequency on Energy Restricted Diet on Performance of Finishing Pigs (Exp. 3)[a]

	Frequency of feeding per day			
Item	2 Modified	2	6	SE
ADG, lb	1.12 [b]	1.14 [b]	1.34 [c]	0.06
ADFI, lb	3.65	3.66	3.65	0.00
F/G	3.23 [b]	3.23 [b]	2.70 [c]	0.15
CV of gain, %	4.01	4.46	4.75	0.55

[a]Each value is the mean of eight replications with 10 pigs (initially 156 lb) per pen. Pens that were fed twice daily received feed at 0700 and 1500 h. Pens that were fed six times a day received feed at 0700, 0800, 0900, 1500, 1600, and 1700 h, respectively. Feed drops were adjusted every 14 d based on the average weight of pigs. Pens fed the 2 modified treatment were fed twice daily with feed delivered directly onto the concrete floor.
[bc]Values within a row lacking a common superscript letter are different (*P*<0.05).

Table 7. Effect of Feeding Frequency on Energy Restricted Diet on Performance of Finishing Pigs (Exp. 4)[a]

	Frequency of Feeding per Day			
Item	2	6	SE	*P*-value (*P* <)
Low feed intake[b]				
ADG, lb	1.03	1.396	0.10	0.01
ADFI, lb	3.55	3.549	0.00	0.26
F/G	3.45	2.56	0.14	0.01
CV of gain, %	4.62	4.24	0.27	0.35
High feed intake[c]				
ADG, lb	1.40	1.563	0.10	0.06
ADFI, lb	4.52	4.513	0.00	0.63
F/G	3.23	2.86	0.17	0.05
CV of gain, %	4.12	3.53	0.27	0.15

[a]Each value is the mean of eight replications with 10 pigs (initially 156 lb) per pen. Pens that were fed twice daily received feed at 0700 and 1500 h. Pens that were fed six times a day received feed at 0700, 0800, 0900, 1500, 1600, and 1700 h, respectively. Feed drops were adjusted every 14 d based on the average weight of pigs.
[b]Pigs were fed to gain 1.75 lb/d based on NRC (1998) values.
[c]Pigs were fed to gain 2.1 lb/d based on NRC (1998) values.