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Effects of an enteric disease challenge on growth, nitrogen retention, and immune status indicators in growing pigs

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EFFECTS OF AN ENTERIC DISEASE CHALLENGE ON GROWTH, NITROGEN RETENTION, AND IMMUNE STATUS INDICATORS IN GROWING PIGS

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Summary

Thirty-five growing pigs (initially 65 ± 2 lb) were used in a metabolism study to determine the effects of a single enteric disease challenge on N retention, growth performance, and blood immunological variables. Twenty-one pigs were challenged with *Salmonella typhimurium*, and six pigs were assigned to an ad libitum-fed, nonchallenged control group. Eight additional nonchallenged pigs were pair-fed the feed intake of an *S. typhimurium* challenged counterpart. There were five 4 d collection periods (d 4 to 7, d 8 to 11, d 12 to 15, d 16 to 19, and d 22 to 25), with the *S. typhimurium* challenge occurring on d 8. Serum haptoglobin concentration increased in the disease-challenged pigs, when compared to both nonchallenged treatments Growth performance and N retention were decreased temporarily during the immune challenge period but recovered to levels similar to those of nonchallenged control pigs by the end of the experiment on d 25. These results suggest that a single acute disease challenge may not be accompanied by large compromises in growth performance and lean growth rate.

(Key Words: Growing Pigs, Nitrogen Retention, Disease Challenge.)

Introduction

Chronic disease challenges that restrict lean growth potential have been minimized by wide-scale adoption of all-in/all-out, multi-site production, and segregated early weaning. However, short-duration, acute disease challenges still occur. An acute disease challenge usually results from a pathogen infecting immune-naive groups of pigs. The pathogen spreads rapidly within the group, and within a short period, immunity develops and performance partially recovers. Although lean growth rate has been improved dramatically in high-health production systems, acute disease challenges appear to be responsible for a large majority of the variation in lean growth rate between groups of pigs and among individuals within a group of pigs.

Research at Iowa State University and elsewhere has established that protein metabolism is influenced negatively in immune-challenged pigs. Those experiments were designed to characterize the effects of chronic immune challenges typical in continuous-flow production systems. These chronic disease challenges may not be reflective of typical disease processes observed in most progressive swine production systems. Our objective was to characterize the effects of an acute disease challenge in pigs by measuring changes in protein metabolism using nitrogen (N) retention techniques. Furthermore, we wanted to characterize the change in several plasma immune status indicators and a growth mediator before, during, and after an acute disease challenge.

Procedures

The experimental protocol used in this study was approved by the KSU Animal

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Care and Use Committee. Thirty-five nonlittermate high-health barrows (PIC C22 × L326; initially 65 ± 2 lb) obtained from a herd without clinical evidence of a *Salmonella typhimurium* infection were blocked by weight and time and allotted to one of three experimental treatments. Pigs were selected in groups of five or six from the same farrowing group and were assigned randomly to either the *Salmonella* challenge or control group. Within the control group, pigs were assigned randomly to receive ad libitum feed intake or to be pair-fed the previous day's feed intake of an assigned *Salmonella*-challenged pig. Once the pair-fed control pigs were allotted to a *Salmonella*-challenged pig, they were fed the feed intake of that same pig throughout all periods. The pair-feeding was performed to elicit the responses independent of feed intake. Water was supplied at 2.5:1 ratio with feed on a wt:wt basis. All pigs were fed and watered twice daily at 6:30 a.m. and 6:30 p.m. Orts were collected just prior to the next feeding. Because of the expected greater variation in performance of the *S. typhimurium* group, 21 pigs were assigned to the *Salmonella* group, with 8 pigs control pair-fed, and 6 control ad libitum fed pigs. All pigs were fed a common corn-soybean meal diet formulated to 1.15% total lysine, with no synthetic amino acids, added fat, or antibiotics (Table 1). There were five 4-d collection periods (d 4 to 7, d 8 to 11, d12 to 15, d 16 to 19, and d 22 to 25), with the *S. typhimurium* challenge occurring on d 8. These included a prechallenge period, a challenge period, two recovery periods, and a postchallenge period. The later was selected to be at least 14 d postchallenge. Pigs assigned to the *Salmonella* challenge treatment were inoculated intragastrically by oral catheter with 10^9 cfu *S. typhimurium.*

All pigs were housed in two similar environmentally controlled rooms based upon health status and were kept in adjustable individual stainless steel metabolism cages (5 ft × 2 ft) that allowed separate collection of feces and urine. The marker to marker method (.5% ferric oxide in the first and eighth subsequent meal) was used to determine the beginning and end of feces collection for a period. Feces were collected twice daily and stored at 20° F. At the end of each period, feces were autoclaved to kill pathogenic activity before being homogenized and subsampled. The fecal subsamples then were analyzed for N and DM. Urine was collected daily in polypropylene bottles containing 75 mL of 6 *N* HCl. Ten percent of the daily urine volume was subsampled and stored at 20° F until laboratory analysis. Urine was centrifuged at 2000 g to remove particulate matter and then was analyzed for N and DM. Feed samples were ground through a 1mm screen before analysis of N and DM. Feed, urine, and feces were analyzed for N on an as-is basis to minimize any loss of gaseous ammonia before analysis.

Table 1. Diet Composition

Ingredient	%
Corn	64.04
Soybean meal, 46.5% CP	32.89
Monocalcium phosphate	1.22
Limestone	1.10
Salt	.35
Vitamin premix	.25
Trace mineral premix	.15

[a]Diet was formulated to contain 1.15% lysine, .75% Ca and .65% P.

Blood samples were drawn via jugular venapuncture using heparinized, serum, and EDTA vacuum tubes on d 5, 9, 13, 17, and 23 at least 2 h postprandial to measure the time course change in segmented neutrophils, monocytes, plasma concentrations of insulin-like growth factor-I (IGF-I), and serum haptogolobin concentrations.

All data were analyzed as a randomized incomplete block design using a mixed model procedure with repeated measures. Pigs were blocked by initial weight and time, with individual pig as the experimental unit. Periodic samples by pig were used for the repeated measures. Linear and quadratic polynomial contrasts were used to determine the effects of *Salmonella* challenge over time on all response criteria.

Results and Discussion

A disease status by time interaction (P<.05) was observed for ADG (Table 2). The interaction was a result of decreased ADG (P<.01) from d 8 to 11 for the *S. typhimurium*-challenged pigs versus the ad libitum-fed control pigs. The pair-fed control pigs tended to have intermediate ADG compared to both of the other groups (P<.07). A tendency for a disease status by time interaction was observed for ADFI (P<.11), primarily as a result of changes in d 8 to 11 ADFI between the *S. typhimurium*-challenged pigs and the ad libitum-fed control pigs. The d 8 to 25 ADFIs were 4.08, 4.18, and 3.83 lb for the *S. typhimurium* challenged pigs, ad libitum-fed controls, and the pair-fed control pigs, respectively. From d 4 to 7, ADFI was lower for the pair-fed controls when compared to *S. typhimurium*-challenged pigs (P<.05). This initial difference in ADFI likely was a result of the time lag in pair-fed pigs' intake, which was equalized to the *S. typhimurium*-challenged pigs' intake 24 h later. Feed efficiency (G/F) was also worse for *S. typhimurium*-challenged pigs compared to pair-fed controls from d 8 to 11 (P<.05). In general, differences in growth performance were observed only during the d 8 to 11 challenge period.

Table 2. Effects of *S. typhimurium* Challenge and Feeding Regimen on Growth Performance in 65 to 125 lb Pigs[a]

	S. typhimurium	Nonchallenged				
	Ad libitum	Ad libitum	Pair-fed	Probability (P <)		
Item[b]	(Trt 1)	(Trt 2)	(Trt3)	1 vs. 2	1 vs. 3	2 vs. 3
Pigs per treatment	21	6	8			
Day 4 to 7						
ADG, lb	2.54 ± .22	2.25 ± .39	2.62 ± .34	.52	.85	.48
ADFI, lb	3.52 ± .23	3.01 ± .31	3.02 ± .28	.06	.04	.96
G/F	.73 ± .10	.81 ± .18	.91 ± .16	.70	.31	.65
Day 8 to 11						
ADG, lb	1.36 ± .22	3.05 ± .39	2.09 ± .34	.01	.07	.06
ADFI, lb	2.92 ± .23	3.61 ± .31	3.07 ± .28	.01	.53	.08
G/F	.20 ± .10	.84 ± .18	.62 ± .16	.01	.02	.36
Day 12 to 15						
ADG, lb	2.42 ± .22	1.93 ± .39	2.48 ± .34	.26	.88	.28
ADFI, lb	4.00 ± .23	4.17 ± .31	3.64 ± .28	.53	.14	.09
G/F	.62 ± .10	.48 ± .18	.74 ± .16	.49	.51	.27
Day 16 to 19						
ADG, lb	2.23 ± .22	2.34 ± .39	2.42 ± .34	.80	.63	.87
ADFI, lb	4.30 ± .23	4.20 ± .31	4.11 ± .28	.70	.42	.76
G/F	.53 ± .10	.55 ± .18	.59 ± .16	.90	.73	.87
Day 22 to 25						
ADG, lb	2.35 ± .22	2.48 ± .39	2.06 ± .34	.77	.47	.41
ADFI, lb	4.99 ± .24	5.02 ± .31	4.71 ± .28	.92	.25	.32
G/F	.48 ± .10	.50 ± .18	.45 ± .16	.91	.89	.84
Day 8 to 25						
ADG, lb	2.11 ± .16	2.43 ± .24	2.24 ± .22	.21	.58	.49
ADFI, lb	4.08 ± .23	4.18 ± .28	3.83 ± .27	.68	.22	.15
G/F	.49 ± .06	.58 ± .11	.59 ± .09	.44	.34	.94

[a]Thirty five pigs were used in a randomized incomplete block design with individual pig as the experimental unit. *S. typhimurium* challenge occurred on d 8. Effects were analyzed using a mixed model with repeated measures. Feed efficiency is expressed as gain:feed (G/F) instead of feed:gain (F/G).

[b]A status × time interaction was observed for ADG (P<.05). Both linear and quadratic time effects (P<.05) were observed for ADFI. A linear time effect (P<.05) was observed for G/F.

A disease status by time interaction also was observed for DM (P<.05) and N (P<.06) digestibility (Table 3). The interaction for DM resulted from d 16 to 19 and d 22 to 25 DM digestibility being greater for *S. typhimurium*-challenged pigs when compared to control ad libitum-fed pigs (P<.05). Dry matter digestibility from d 12 to 25 was also greater for the *S. typhimurium*-challenged pigs versus the pair-fed controls (P<.10). As the pair-fed control pigs increased feed intake from d 12 to 15, they also had increased DM digestibility when compared to the ad libitum-fed control pigs (P<.03). This resulted in increased d 8 to 25 DM digestibility for the *S. typhimurium*-challenged pigs versus the ad libitum-fed control pigs (P<.05). Additionally, DM digestibility tended to be better for the pair-fed control pigs when compared to the ad libitum-fed control pigs from d 8 to 25 (P<.08). The differences in digestibility may have been due to improved metabolic efficiency and further indicate that compensatory gain occurred as ADFI increased for the *S. typhimurium*-challenged pigs during the recovery and postchallenge periods.

A disease status by time interaction was observed for fecal N and retained N (P<.05; Table 4). The interaction resulted from decreased N retention during the acute challenge period (d 8 to 11), indicating a reduction in lean growth rate for both pair-fed control and the *S. typhimurium*-challenged pigs as compared to the ad libitum-fed control pigs (Figure 1). The fecal N interaction was a result of changes in ADFI and increased digestibility from d 16 to 19 and d 8 to 25 for the *S. typhimurium*-challenged pigs, and the pair-fed control pigs compared to the ad libitum-fed control pigs (P<.05). Tendencies for differences in N intake, N retention, and fecal N (P<.10) between pair-fed and ad lib controls were results of decreases in the pair-fed pigs' ADFI from d 8 to 11. Nitrogen intake was similar across treatments (quadratic, P<.05), except for the tendency towards a reduction associated with d 8 to 11 ADFI for the *S. typhimurium*-challenged (P<.01) and pair-fed control pigs (P<.08) versus the ad libitum-fed controls. Similarly, urine N increased over time as a result of increased intake (quadratic, P<.05).

A tendency for a disease status by time interaction was observed for the percentage of N intake retained (P<.13; Table 5). From d 8 to 11, N retention efficiency, both as percentage of N intake and percentage of absorbed N, was worse for *S. typhimurium*-challenged pigs versus control ad libitum-fed pigs (P<.05), with intermediate efficiency for the pair-fed controls (P<.07). The d 8 to 11 N retention efficiency differences between treatments indicate that the change in protein metabolism for the *S. typhimurium*-challenged pigs was due to more than the effect of reduced ADFI and related reductions in N retention. The differences in d 8 to 11 N retention efficiency and feed utilization indicate two things. First, during the acute disease challenge, the *S. typhimurium*-challenged pigs were partitioning nutrients to the immune response and not to growth. Secondly, the poorer utilization by the *S. typhimurium*-challenged pigs versus pair-fed controls indicates that only part of the decreased growth performance and N retention was explained by decreased ADFI. The remainder of the lost metabolic efficiency was unique to the immune challenge and was likely due to the increased body heat from loss fever and short-term changes in gastrointestinal physiology associated with an acute enteric disease challenge.

A disease status by time interaction was observed for haptoglobin concentration (P<.05; Table 6). Day 9 and 13 haptoglobin levels were highest for the *S. typhimurium*-challenged pigs versus the ad libitum-fed control pigs (P<.05). Haptoglobin levels of pair-fed control pigs were intermediate to those of both other treatments and differed from those of the *S. typhimurium*-challenged pigs on d 13 and d 17 (P<.05; P<.10, respectively). The haptoglobin response indicates that concentrations increased and then decreased for the challenge pigs during and after the challenge period, while remaining relatively flat for the pigs in both control treatments (Figure 2). This response

is consistent with previous research indicating that acute phase proteins increase in concentration with an increase in immunological activity.

Insulin-like growth factor-I concentration increased regardless of disease status from d 4 to 25 (linear, P<.05; Figure 3). By d 17, IGF-I levels were highest in the *S. typhimurium*-challenged pigs, and differed from those of the pair-fed controls on d 17 and the ad libitum-fed control pigs on d 23 (P<.05). A tendency for increased d 17 IGF-I levels was observed for the *S. typhimurium*-challenged pigs versus the ad libitum-fed control pigs (P<.10). The increased levels of IGF-I were concurrent with improvements in growth performance and N retention of the *S. typhimurium*-challenged pigs during the recovery and postchallenge periods.

A disease status by time interaction was observed for segmented neutrophils (P<.05). A numerical reduction in d 13 segmented neutrophils for the *S. typhimurium*-challenged pigs was observed (P>.10). By d 17, however, segmented neutrophils increased for the *S. typhimurium*-challenged pigs when compared to both control treatments (P<.05). This response is consistent with previous research indicating that the segmented neutrophil count will decrease during a disease challenge and subsequently increase during recovery and postchallenge periods.

Monocyte concentration tended to decrease regardless of status from d 4 to 25, with the greatest decrease in monocyte concentration occurring after d 13 (linear, P<.09). A tendency for increased levels of d 17 monocytes was observed for the *S. typhimurium*-challenged pigs versus the ad libitum-fed control pigs (P<.10).

A major portion of the differences in growth performance and N retention between *S. typhimurium*-challenged pigs and ad libitum-fed control pigs was due to feed intake differences. However, the differences between the pair-fed controls and ad libitum-fed controls indicate the differences in protein metabolism related to feed intake. The additional decreases in growth performance and N retention for the *S. typhimurium*-challenged pigs were due to changes in metabolic processes in response to the disease challenge. The changes in blood growth and immune parameters are also consistent with the results observed for growth performance and N retention.

The results of this experiment are consistent with previous studies, indicating that protein metabolism, as indicated by N retention, and growth performance are affected negatively by immune activation. They also indicate that an oral dose of 10^9 cfm of *S. typhimurium* is sufficient to produce an acute immune response. These results further indicate that most of the effects from an acute enteric immune challenge on protein metabolism are due to decreased feed intake. In addition, factors unique to the acute immune response, such as increased body heat loss from fever and short-term changes in gastrointestinal physiology, cause further short-term reduction in performance.

Perhaps the most surprising result of this experiment is the lack of long-term changes in N retention and growth performance. In addition, the compensatory growth performance and N retention driven by elevated IGF-I levels indicate that few long term effects will be associated with acute immune activity. In comparison, our results are consistent with research using a noninfectious immune challenge in chickens. A lack of long-term growth reduction and compensatory gain were reported consistently.

Based upon field experience, pigs subjected to an enteric disease immune challenge have shown longer term reductions in lean growth rate. This decrease in overall performance is due to the interplay of other factors outside of the acute disease challenge. In contrast to typical field conditions, the pigs used in this experiment were maintained in a near ideal environment, with minimal outside stress and a similar infectious dose. The lack of additional stressors such as social interaction with penmates, reinfection from

other pigs, and competition for feed and water likely contributed to the rapid recovery in this experiment. The results of this experiment indicate that a single acute disease outbreak may not be accompanied by large compromises in growth performance and lean growth rate. However, short-term changes in lean growth rate are due to both feed intake reductions and repartitioning nutrients to the immune response.

Table 3. Effects of *S. typhimurium* Challenge and Feeding Regimen on Dry Matter and Nitrogen Digestibility in 65 to 125 lb Pigs[a]

	S. typhimurium	Nonchallenged				
	Ad libitum	Ad libitum	Pair-fed	Probability (P <)		
Digestibility[b], %	(Trt 1)	(Trt 2)	(Trt 3)	1 vs. 2	1 vs. 3	2 vs. 3
Day 4 to 7						
Dry matter	87.5 ± .37	87.2 ± .77	87.1 ± .64	.72	.55	.89
Nitrogen	90.4 ± 1.26	89.4 ± 2.68	89.8 ± 2.20	.74	.81	.92
Day 8 to 11						
Dry matter	86.3 ± .36	86.4 ± .64	86.3 ± .55	.83	.98	.84
Nitrogen	83.8 ± 1.20	88.1 ± 2.19	89.2 ± 1.91	.09	.02	.68
Day 12 to 15						
Dry matter	86.7 ± .36	86.0 ± .64	87.8 ± .55	.27	.10	.03
Nitrogen	89.5 ± 1.20	88.2 ± 2.19	90.0 ± 1.91	.58	.85	.53
Day 16 to 19						
Dry matter	87.6 ± .36	85.0 ± .64	85.9 ± .55	.01	.02	.27
Nitrogen	89.5 ± 1.20	84.2 ± 2.19	85.9 ± 1.91	.04	.11	.56
Day 22 to 25						
Dry matter	88.0 ± .36	86.5 ± .64	86.9 ± .55	.04	.10	.63
Nitrogen	89.7 ± 1.20	85.7 ± 2.19	86.7 ± 1.91	.11	.28	.75
Day 8 to 25						
Dry matter	87.1 ± .19	86.1 ± .36	86.8 ± .31	.02	.45	.08
Nitrogen	88.1 ± .71	86.6 ± 1.25	88.0 ± 1.09	.28	.93	.38

[a]Thirty five pigs were used in a randomized incomplete block design with individual pig as the experimental unit. *S. typhimurium* challenge occurred on d 8. Effects were analyzed using a mixed model with repeated measures.

[b]A status × time interaction was observed for DM digestibility (P<.05) and N digestibility (P<.06).

Table 4. Effect of *S. typhimurium* Challenge and Feeding Regimen on Nitrogen Balance in 65 to 125 lb Pigs[a]

	S. typhimurium	Nonchallenged				
	Ad libitum	Ad-libitum	Pair-fed	Probability (P <)		
Item[b], g/d	(Trt 1)	(Trt 2)	(Trt 3)	1 vs. 2	1 vs. 3	2 vs. 3
Day 4 to 7						
N intake	50.7 ± 3.6	43.6 ± 4.6	44.6 ± 4.3	.07	.08	.83
Fecal N	5.4 ± .72	5.3 ± 1.1	5.0 ± .9	.86	.64	.85
Urine N	15.9 ± 2.3	13.6 ± 2.9	14.1 ± 2.7	.36	.41	.87
N retained	30.7 ± 1.9	25.4 ± 3.7	25.5 ± 2.7	.18	.13	.98
Day 8 to 11						
N intake	42.4 ± 3.6	52.3 ± 4.6	44.5 ± 4.3	.01	.54	.08
Fecal N	5.9 ± .71	5.8 ± .9	4.5 ± .9	.90	.07	.19
Urine N	17.0 ± 2.3	16.2 ± 2.9	16.7 ± 2.7	.71	.86	.85
N retained	19.6 ± 1.9	30.1 ± 3.1	23.2 ± 2.7	.002	.23	.07
Day 12 to 15						
N intake	58.0 ± 3.6	60.5 ± 4.6	52.9 ± 4.3	.51	.15	.09
Fecal N	6.3 ± .71	6.8 ± .9	5.2 ± .9	.51	.15	.09
Urine N	18.9 ± 2.3	18.9 ± 2.9	16.4 ± 2.7	.98	.26	.36
N retained	33.0 ± 1.9	34.5 ± 3.1	31.1 ± 2.7	.65	.54	.38
Day 16 to 19						
N intake	62.3 ± 3.6	60.9 ± 4.6	59.6 ± 4.3	.72	.44	.76
Fecal N	6.7 ± .71	9.2 ± .9	8.3 ± .9	.005	.04	.35
Urine N	22.0 ± 2.3	23.1 ± 2.9	22.1 ± 2.7	.65	.94	.73
N retained	33.7 ± 1.9	28.4 ± 3.1	29.1 ± 2.7	.11	.12	.87
Day 22 to 25						
N intake	72.1 ± 3.6	72.8 ± 4.6	68.3 ± 4.3	.87	.28	.31
Fecal N	7.7 ± .72	9.9 ± .9	8.8 ± .9	.008	.13	.25
Urine N	28.8 ± 2.3	32.1 ± 2.9	28.7 ± 2.7	.18	.97	.22
N retained	35.8 ± 1.9	30.5 ± 3.1	30.6 ± 2.7	.12	.09	.98
Day 8 to 25						
N intake	56.9 ± 3.3	58.0 ± 3.9	54.0 ± 3.7	.70	.29	.20
Fecal N	6.4 ± .67	7.5 ± .76	6.4 ± .73	.03	.97	.05
Urine N	20.4 ± 2.1	20.8 ± 2.4	19.6 ± 2.3	.82	.61	.51
N retained	30.5 ± 1.3	30.1 ± 1.9	28.1 ± 1.7	.83	.16	.34

[a]Thirty five pigs were used in a randomized incomplete block design with individual pig as the experimental unit. *S. typhimurium* challenge occurred on d 8. Effects were analyzed using a mixed model with repeated measures.

[b]Status × time interactions were observed for both fecal N and N retained (P<.05). Linear and quadratic time effects (P<.05) were observed for N intake, and urine N.

Table 5. Effect of *S. typhimurium* Challenge and Feeding Regimen on N Retention Efficiency in 65 to 125 lb Pigs[a]

N Retention Efficiency, %	*S. typhimurium* Ad libitum (Trt 1)	Nonchallenged Ad libitum (Trt 2)	Nonchallenged Pair-fed (Trt 3)	Probability (P <) 1 vs. 2	1 vs. 3	1 vs. 3
Day 4 to 7						
% of ADFI	59.48 ± 4.0	55.01 ± 8.1	55.03 ± 6.7	.61	.55	.61
% of absorbed	65.52 ± 7.2	64.21 ± 1.6	63.20 ± 1.3	.94	.88	.94
Day 8 to 11						
% of ADFI	38.59 ± 3.9	57.01 ± 6.7	51.73 ± 5.9	.02	.05	.02
% of absorbed	34.44 ± 6.9	65.49 ± 1.3	58.72 ± 1.1	.04	.07	.04
Day 12 to 15						
% of ADFI	57.82 ± 3.9	57.25 ± 6.7	59.43 ± 5.9	.94	.81	.94
% of absorbed	63.92 ± 6.9	65.59 ± 1.3	66.67 ± 1.1	.91	.83	.91
Day 16 to 19						
% of ADFI	55.06 ± 3.9	46.59 ± 6.7	49.18 ± 5.9	.26	.38	.26
% of absorbed	60.97 ± 6.9	56.22 ± 1.3	57.88 ± 1.1	.75	.81	.75
Day 22 to 25						
% of ADFI	50.98 ± 3.9	41.09 ± 6.7	44.93 ± 5.9	.19	.37	.19
% of absorbed	56.36 ± 6.9	48.77 ± 1.3	52.30 ± 1.1	.61	.76	.61
Day 8 to 25						
% of ADFI	52.19 ± 2.5	51.23 ± 3.7	51.95 ± 3.3	.80	.95	.86
% of absorbed	56.09 ± 3.3	59.69 ± 6.1	59.49 ± 5.3	.60	.58	.98

[a]Thirty five pigs were used in a randomized incomplete block design with individual pig as the experimental unit. *S. typhimurium* challenge occurred on d 8. Effects were analyzed using a mixed model with repeated measures.

[b]A status × time interaction (P<.05) was observed for N retention efficiency as a percent of ADFI.

Table 6. Effects of *S. typhimurium* Challenge and Feeding Regimen on Blood Growth and Immune Status Indicators in 65 to 125 lb Pigs[a]

	S. typhimurium	Nonchallenged		Probability (P <)		
	Ad-libitum	Ad-libitum	Pair-fed			
Item[b]	(Trt 1)	(Trt 2)	(Trt 3)	1 vs. 2	1 vs. 3	2 vs. 3
Day 5						
Haptoglobin, mg Hgb/dL	39 ± 6.3	48 ± 8.6	42 ± 7.9	.22	.67	.46
IGF-I, ng/mL	342 ± 34.7	289 ± 49.9	305 ± 47.2	.28	.42	.78
Seg. Neutrophil/mL	5987 ± 1035	6680 ± 1530	7803 ± 1445	.65	.21	.53
Monocyte/mL	989 ± 127	513 ± 201	1092 ± 188	.03	.61	.02
Day 9						
Haptoglobin, mg Hgb/dL	57 ± 6.3	39 ± 8.6	51 ± 7.9	.02	.39	.18
IGF-I, ng/mL	293 ± 35.0	331 ± 49.9	323 ± 45.2	.44	.50	.88
Seg. Neutrophil/mL	7603 ± 1046	5796 ± 1530	6538 ± 1377	.24	.44	.67
Monocyte/mL	988 ± 129	864 ± 201	892 ± 178	.56	.62	.91
Day 13						
Haptoglobin, mg Hgb/dL	69 ± 6.3	31 ± 8.6	47 ± 7.9	.001	.002	.07
IGF-I, ng/mL	306 ± 35.1	333 ± 49.9	334 ± 45.2	.58	.53	.99
Seg. Neutrophil/mL	5729 ± 1065	6117 ± 1637	6381 ± 1445	.82	.66	.89
Monocyte/mL	1049 ± 131	847 ± 216	820 ± 188	.38	.26	.92
Day 17						
Haptoglobin, mg Hgb/dL	48 ± 6.3	38 ± 8.6	34 ± 7.9	.22	.06	.66
IGF-I, ng/mL	433 ± 34.7	340 ± 49.9	326 ± 47.2	.06	.02	.81
Seg. Neutrophil/mL	12745 ± 1035	6264 ± 1530	6801 ± 1377	.001	.001	.76
Monocyte/mL	973 ± 127	578 ± 201	712 ± 178	.06	.17	.58
Day 23						
Haptoglobin, mg Hgb/dL	39 ± 6.8	28 ± 8.6	39 ± 7.9	.20	.99	.26
IGF-I, ng/mL	401 ± 35.1	293 ± 49.9	357 ± 45.2	.03	.32	.25
Seg. neutrophil/mL	7705 ± 1073	5530 ± 1530	5942 ± 1377	.16	.21	.81
Monocyte/mL	863 ± 133	664 ± 201	600 ± 178	.35	.18	.79

[a]Thirty five pigs were used in a randomized incomplete block design with individual pig as the experimental unit. *S. typhimurium* challenge occurred on d 8. Results are expressed for serum haptoglobin, plasma IGF-I, and whole blood segmented neutrophils and monocytes. Effects were analyzed using a mixed model with repeated measures.

[b]A status × time interaction (P<.05) was observed for haptoglobin and segmented neutrophils. A linear time effect (P<.05) was observed for IGF-I. A tendency for a linear time effect (P<.09) was observed for monocyte levels.

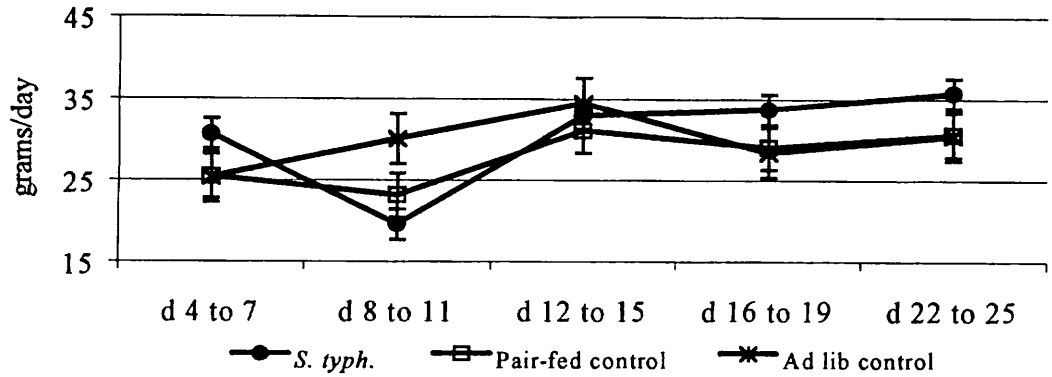

Figure 1. Effects of *S. typhimurium* Challenge and Feeding Regimen on Nitrogen Retention in 65 to 125 lb Pigs.

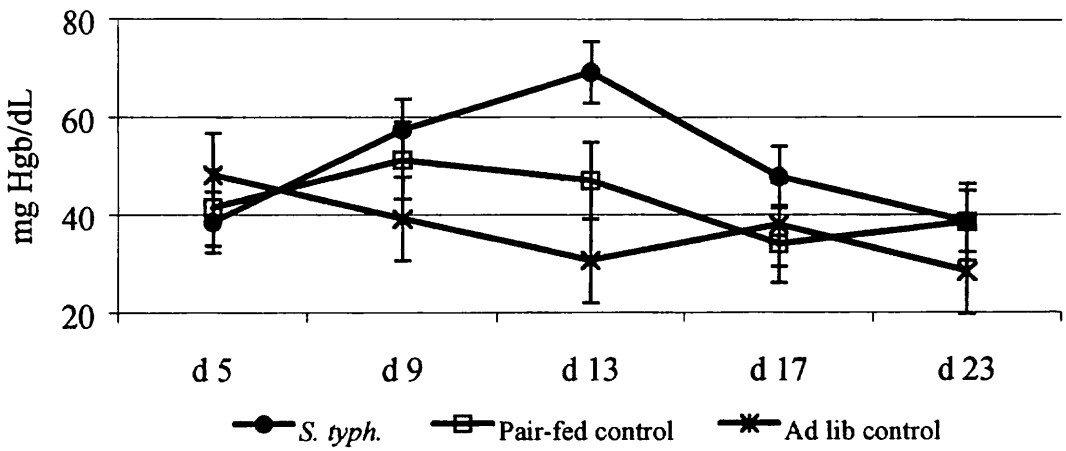

Figure 2. Effects of *S. typhimurium* Challenge and Feeding Regimen on Serum Haptoglobin Levels in 65 to 125 lb Pigs.

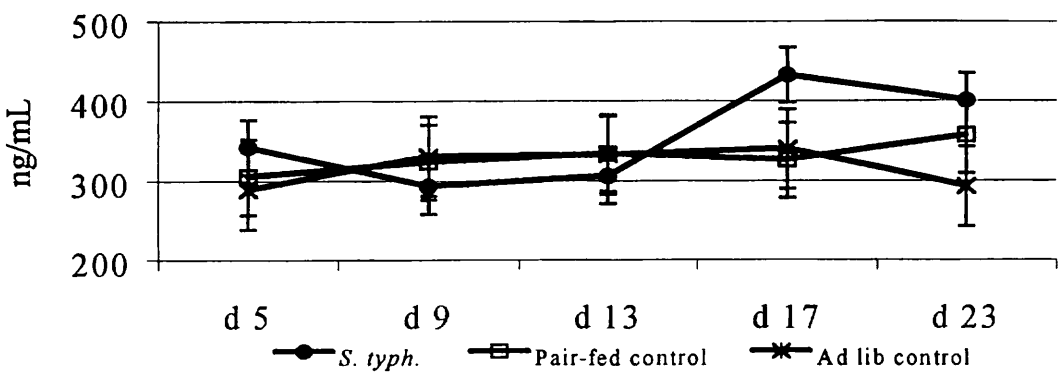

Figure 3. Effects of *S. typhimurium* Challenge and Feeding Regimen on Plasma IGF-I Levels in 65 to 125 lb Pigs.