ORIGINAL RESEARCH

Holck JT, Schinkel AP, Coleman JL, et al. The influence of environment on the growth of commercial finisher pigs. *Swine Health and Production*. 1998;6(4):141–149.

The influence of environment on the growth of commercial finisher pigs

J. Tyler Holck, DVM, MS; Allan P. Schinckel, PhD; Jack L. Coleman, DVM; Vincent M. Wilt, DVM; Michael K. Senn, DVM, MS; Brad J. Thacker, DVM, PhD; Eileen L. Thacker, DVM, PhD; Alan L. Grant, PhD

Summary

Objective: To quantify the influence of the commercial finishing environment on growth and to evaluate potential biomarkers of growth performance.

Methods: Forty–eight barrows were selected at 11 weeks of age from a commercial nursery and randomly assigned either to the environments of the adjoining commercial grower and finisher buildings (n=24) (COMM group) or an unrestricting research environment (n=24) (UNRES group). Pigs were weighed at biweekly intervals from placement at 30 kg (65 lb) liveweight until slaughter. Backfat thickness and loin eye area were measured by B-mode ultrasound every 28 days until the mean liveweight of the group was 91 kg (200 lb) and then biweekly to 120 kg (265 lb), when the entire group went to slaughter. Fat-free carcass lean and total carcass fat were predicted using equations including liveweight, ultrasonic backfat depth, and ultrasonic loin eye measurements. Serum collected at 11, 13, 15, 19, and 23 weeks of age were evaluated for α-1-acid glycoprotein (AGP), insulin-like growth factor-1 (IGF-1), and haptoglobin. Whole blood was collected at 11 and 23 weeks of age for lymphocyte phenotyping (CD4, CD8).

Results: UNRES group pigs had higher ($P < .001$) average daily liveweight gain, fat-free lean gain, and fat gain compared to pigs raised in the commercial environment. The liveweight gain and lean growth advantage of UNRES group pigs compared to COMM group pigs were immediate and consistent at each measurement. Lean gain increased from 30 to 52 kg (66 to 115 lb) bodyweight and then declined in both environments. UNRES group pigs had lower AGP ($P < .02$) and higher IGF-1 ($P < .10$) compared to COMM group pigs from 13–23 weeks of age. CD4 values were also significantly ($P < .05$) lower for the UNRES group pigs at 23 weeks of age.

Implications: The commercial grow-finish environment reduced liveweight, lean, and fat growth to 70% of that achieved under less limiting research conditions. Differences in AGP and CD4 values were detected between environments, suggesting that they may be useful as biomarkers in the finisher stage of commercial production.

Keywords: swine, environment, growth, carcass quality, biomarkers

Received: June 6, 1997
Accepted: April 18, 1998

The commercial swine industry in the United States is characterized by fierce competition to improve production efficiencies while maintaining or expanding capacity.[1] The majority of costs in production are accrued during the finishing phase; thus, growth performance during finishing is critical to the financial success of a swine operation. There are three main factors that influence growth performance:

- biological potential (genetics, gender);
- nutrient intake; and
- the growing environment.

Schinckel[2] has estimated that the United States commercial swine industry is achieving only 65%–75% of its genetic potential for growth due to limitations associated with the growing environment. Potential factors limiting growth include physical (thermal, stocking density, feed and water access), social (pigs per pen, movement), and microbial (sanitation, segregation) conditions that may contribute to physiological and immunological stress. However, the impact of the commercial environment on growth performance and composition has not been well documented or quantified.

The possibility of monitoring a pig's response to its environment with physiological markers, or biomarkers, is intriguing. Biomarkers could potentially affect the commercial industry by quantifying the pig's response to its environment and by providing estimates of lean gain. Expected differences in biomarker values due to environment must be of sufficient magnitude and duration to be accurately detected.

Acute-phase proteins are a class of proteins produced by the liver in response to cytokines associated with inflammation, infection, tissue injury, or neoplastic disease. Acute-phase proteins function to restore biologic homeostasis when it is disrupted by injury or infection. Acute-phase proteins are thought to be sensitive but nonspecific physiologic

JTH: Boehringer Ingelheim/NOBL Laboratories, Inc., 2501 N Loop Drive, Amers Iowa 50010, email: jtholck@bi-nobl.com; APS, ALG: Purdue University; JLC: General Veterinary Clinic; VMW: Paris Veterinary Clniic; MKS: Cotswold USA; BJT, ELT: Iowa State University

This article is available online at http://www.aasp.org/shap.html

markers of stress and have been proposed as indicators of pig performance[3] and the impact of specific production practices.[4] In a Japanese study evaluating commercial pigs, α-1-acid glycoprotein (AGP) and haptoglobin were elevated, although only AGP was significantly different from specific-pathogen-free (SPF) pigs.[5] Insulin-like growth factor-1 (IGF-1) is a protein that mediates many of the effects of growth hormone on protein and lipid metabolism. IGF-1 is mitogenic and has been evaluated as a biomarker for protein accretion. A significant correlation between IGF-1 and protein deposition was found in barrows at 30, 60, and 90 kg (66.2, 132.3, and 198.5 lb).[6] Cluster-of-determination (CD) antigens are membrane-associated molecules on lymphocytes; CD4 antigens are found on T-lymphocytes, which recognize class-II major histocompatibility molecules associated with bacterial infections and have been classified as T-helper cells, while CD8 antigens recognize class-I major histocompatibility molecules associated with viral infections and have been classified as cytotoxic T-cells.

In this study, we monitored growth performance parameters (liveweight, ultrasonic backfat depth, ultrasonic loin eye area) and four potential biomarkers of growth (AGP, IGF-1, haptoglobin, CD4/CD8) to investigate the possible limitations of a typical commercial environment on the growth performance of pigs.

Materials and methods

Animal selection

A commercial, three-stage, one-site, farrow-to-finish swine operation in northeast Missouri was selected for this study. The sow herd was serologically positive for porcine reproductive and respiratory syndrome virus (PRRSV), swine influenza virus (SIV), *Actinobacillus pleuropneumoniae* serotype 7, and *Mycoplasma hyopneumoniae*. Forty-eight crossbred (PIC, Camborough-15 dams × Line 326 sires) barrows were selected at the completion of the all-in–all-out (AIAO) nursery stage. The pigs were approximately 11 weeks of age and weighed an average of 30 kg (65 lb), with a range of 23–37 kg (50–82 lb), when the study began.

Treatment (environment)

The pigs were blocked by weight and randomly allotted to either remain in the commercial facility (COMM group)(n=24) or to be transported to a research facility and reared in an unrestricted environment (UNRES group) (n=24). All pigs were individually identified by eartag.

COMM group pigs were moved as a group to one pen in the onsite grower building on day 1 of the study. The power-ventilated, total slat/pull-plug grower building contained 16 pens and was operated on a continuous-flow basis with two different age groups (4 weeks apart) housed at any one time. Trial pens in the grower measured 3.7 m × 4.0 m (12 ft × 13 ft), providing approximately 0.6 m^2 (6.5 sq ft) per head and contained one eight-hole feeder and two nipple waterers. The room temperature in the grower ranged from 18–30°C (64–86°F) during the 8 weeks in which the pigs were in the room. The pigs reared in the commercial facility were moved as a group to a pen in the on-site finisher at 19 weeks of age, as was consistent with the usual pig flow of the commercial operation. The naturally ventilated, double-curtain-sided, partially slatted finisher building was operated AIAO by room. The trial pen in the finisher measured 2.4 m × 7.0 m (8 ft × 23 ft), providing approximately 0.74 m^2 (8 sq ft) per head and contained one 0.8-m (2.5-ft) diameter round feeder and two nipple waterers.

UNRES group pigs were transported 5 hours the morning after allotment (day 1) to a research facility at Iowa State University. The facility contained eight pens with solid concrete floors with solid steel gating between pens. Floors were washed daily. The positively ventilated room was separate from other swine. Each pen measured 2.4 m × 2.7 m (8 ft × 9 ft) and provided approximately 2.23 m^2 (24 sq ft) per head with one two-hole feeder and one nipple waterer. The room temperature in the research facility varied between 16–21°C (61–70°F) during the trial period. The pigs were assigned to one of eight pens by weight in order to equalize mean weights for each pen and they remained in their assigned pens for the entire study.

Growth and composition

All pigs were weighed the day of allotment and every 2 weeks thereafter for the duration of the study. Backfat thickness and loin eye area were measured by real-time ultrasound (Pie Medical 2000, Maastricht, the Netherlands) on the day of allotment and every 4 weeks thereafter until the group mean weight was approximately 91 kg (200 lb) and every 2 weeks thereafter until the end of the trial. All animals were evaluated until the mean weight of the group was approximately 120 kg (265 lb), at which time the entire treatment group was sent to slaughter. Individual carcass data (backfat depth and loin depth) using linear ultrasound (Fat-O-Meter, SFK technologies, Copenhagen, Denmark) were collected at slaughter to estimate the fat-free lean index (FFLI).

Feed

Pigs in both groups were offered feed ad libitum. Both groups were fed identical total amounts of diets one, two, and three (Table 1). The fourth diet was fed until the group achieved the targeted market weight of 120 kg (265 lb). Feed was mixed at both sites and samples were collected for confirmation of nutrient levels by proximate analysis.

Health monitoring

Eight pigs from each group (one from each pen in the UNRES group) were randomly selected at allotment for blood sampling at 11 (allotment), 13, 15, 19, and 23 weeks of age to monitor serostatus to PRRSV, SIV, *A. pleuropneumoniae*, and *M. hyopneumoniae*. Serologic testing was conducted by Oxford Laboratories, Inc., Worthington, Minnesota. Lung lesions (percent pneumonia, PigMON[7]) and turbinate atrophy (mm ventral space) were evaluated at slaughter.

Biomarkers

Aliquots of serum collected at 11,13,15, 19, and 23 weeks of age were evaluated for:

- AGP by radial immunodiffusion (Saikin Kagaku Institute Co. Ltd., Sendai, Japan);
- IGF-1 by radial immunodiffusion as described by Buonomo[8] and

Dahl[9] using recombinant human IGF-1 (Austral Biological, San Romon, California); and
- rabbit anti-IGF-1 (UB3–189; National Hormone and Pituitary Program, Rockville, Maryland), and haptoglobin by an immunoturbidometric method (Purina Mills, St. Louis, Missouri).

Whole blood was collected at 11 and 23 weeks of age for lymphocyte phenotyping using fluorescence activated cell sorter (FACS, Iowa State University, Ames, Iowa).

Statistical analysis

The individual pig was considered the experimental unit for data analysis. Upon selection, pigs were ranked by weight and randomly assigned to treatment within blocks of two animals (24 blocks). The replication by pen in the unrestricted group (three pigs per pen) and lack of replication in the COMM group (all 24 pigs in one pen) was intentional to establish a nonlimiting environment and a representative commercial environment respectively. Feed consumption and efficiencies were calculated but not statistically analyzed due to the lack of replication in the COMM group. Fat-free carcass lean and total carcass fat were predicted using regression equations utilizing liveweight, ultrasound backfat depth, and loin eye area measurements.[10] A coefficient of determination ($r^2 > .75$) was calculated using a linear assumption for bodyweight, backfat depth, loin eye area, total fat, and fat-free lean versus day and weight for each individual animal. Slopes for individual animals were compared by ANOVA (Proc GLM, SAS 1990). Repeated-measures analysis (SAS 1990) was used to analyze AGP, haptoglobin, and IGF for samples collected post allotment (13, 15, 19, and 23 weeks of age). Lymphocyte phenotypes (%CD4, %CD8) were compared by ANOVA at both 11 and 23 weeks of age (SAS 1990).

The data for each environment were also statistically analyzed with a series of nonlinear equations. Live weight gain on test was fit to a three parameter function where:

$$WTG = MW\left(1 - e^{-mt^a}\right)$$

where:

- WTG is live weight on test (kg),
- MW is a prediction of mature weight,
- t is days on test, and
- m and a are growth parameters (e.g., ADG, backfat, etc.).[11]

Weighted least-squares analysis of the liveweight data was accomplished by standardizing the variation in liveweight at each weigh date before using conventional least-squares nonlinear solution methods (Proc NLIN, SAS, 1990). Predicted fat-free lean and carcass-fat mass data were fit to augmented allometric equations:[12]

$$Y = aX^b\left(c - X\right)^d$$

where:

- Y is component mass (kg),
- X is live weight (kg), and
- a, b, c, and d are parameters (e.g., growth, seroprevalence, biomarker concentrations).

The augmented allometric equations were linearized via log-to-log transformation:

$$\log Y = \log a + b \log X + d \log (c-X)$$

Daily carcass fat-free lean and fat growth rates (g per day) were predicted as the product of the derivatives of live weight mass (LWT) with respect to time and component mass (c) on live weight:[12,13]

$$\left(\frac{\partial c}{\partial t} = \frac{\partial LWT}{\partial t}\right) \times \left(\frac{\partial c}{\partial LWT}\right)$$

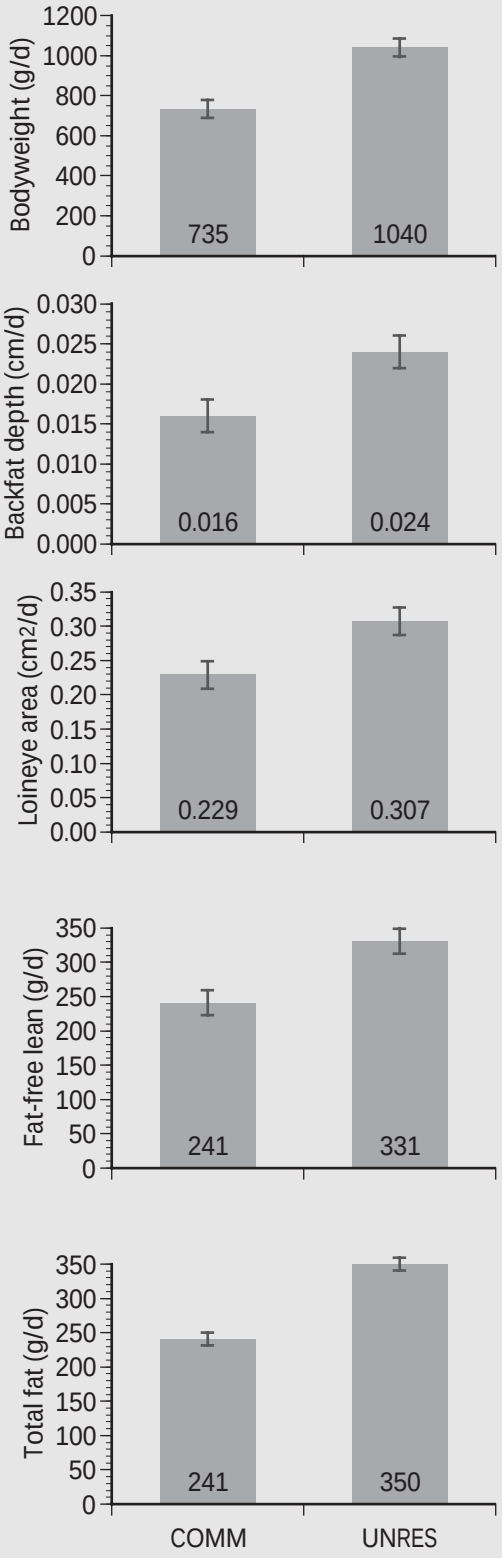
Feed intake data (FI, kg per day) were fit to an exponential function of

Table 1

Diet formulations

Ingredient	Diet one	Diet two	Diet three	Diet four
Corn, lb	1350	1495	1570	1680
Soybean meal (48% CP), lb	480	380	305	215
Akey grow 90, lb	90	–	–	–
Akey grow 65, lb	–	65	65	65
Soy oil, lb	80	60	60	40
Total, lb	**2000**	**2000**	**2000**	**2000**
Nutrient				
Protein, %	17.86	15.27	13.77	12.05
Lysine, %	1.13	0.91	0.81	0.68
Fat, %	7.01	6.14	6.25	5.41
Fiber, %	2.52	2.51	2.48	2.47
Calcium, %	0.66	0.66	0.65	0.64
Phosphorus, %	0.62	0.57	0.55	0.54
Zinc, ppm	115	80	80	80
Selenium, ppm	0.3	0.3	0.3	0.3
ME (kCal/lb)	1529	1514	1516	1496
Other				
Tylosin, g/ton	40	40	40	40
Total fed per group, lb	**2000**	**4000**	**4000**	balance:
			unrestricted	**3304**
			commercial	**5050**

Figure 1



Linear growth results

live weight:

$$FI = e^{b_0 + b_1 \cdot LWT + b_2 \cdot LWT^2}$$

The function was solved by the linear regression:

$$LNY = b_0 + b_1 \cdot LWT + b_2 \cdot LWT^2$$

(Proc GLM, SAS, 1990).

Results

Growth: linear analysis

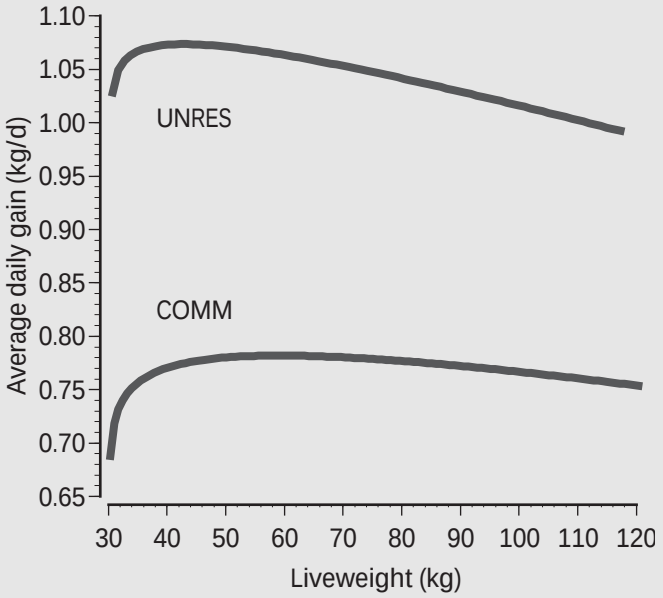
Dramatic differences ($P < .0001$) in bodyweight gain were observed between pigs raised in the two different environments. Mean ADG from 30–120 kg (65–265 lb) bodyweight was significantly higher in the UNRES pigs compared to COMM pigs (Figure 1). UNRES pigs had significantly higher mean liveweight by 2 weeks after allotment compared to COMM pigs and those differences in bodyweights were magnified during the growout period.

UNRES pigs achieved market weight 32 days sooner than COMM pigs. The increased body weights consisted of both fat and lean gain with ($P < .001$) backfat depth (cm) and loin eye area (cm^2) per day differing significantly between groups (Figure 1). Calculated total carcass fat and fat-free carcass lean on a per-day basis differed significantly ($P < .001$) between groups.

Growth: Nonlinear analysis

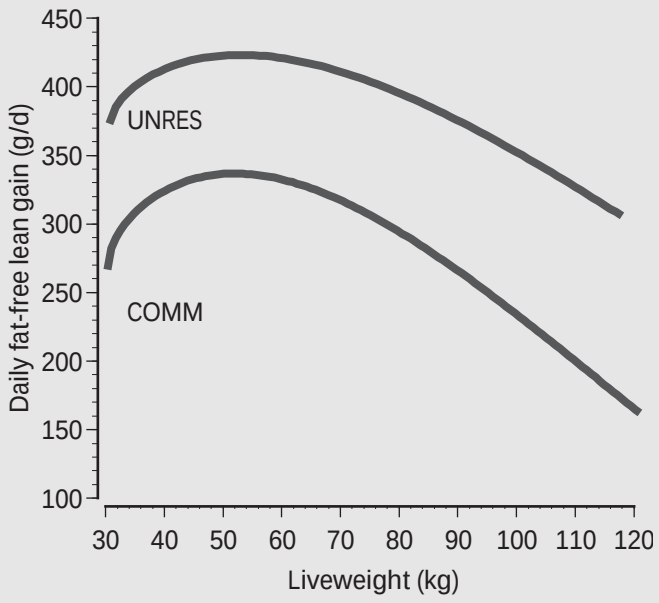
Average daily gain increased slightly in both groups as liveweight increased, reached a maximum, and then decreased slightly until slaughter (Figure 2). COMM group pigs achieved a maximum ADG of 780 g (1.72 lb) at 59.0 kg (130 lb) liveweight, while UNRES pigs achieved a maximum of 1070 g (2.36 lb) ADG at 42 kg (93 lb) liveweight. UNRES

Figure 2



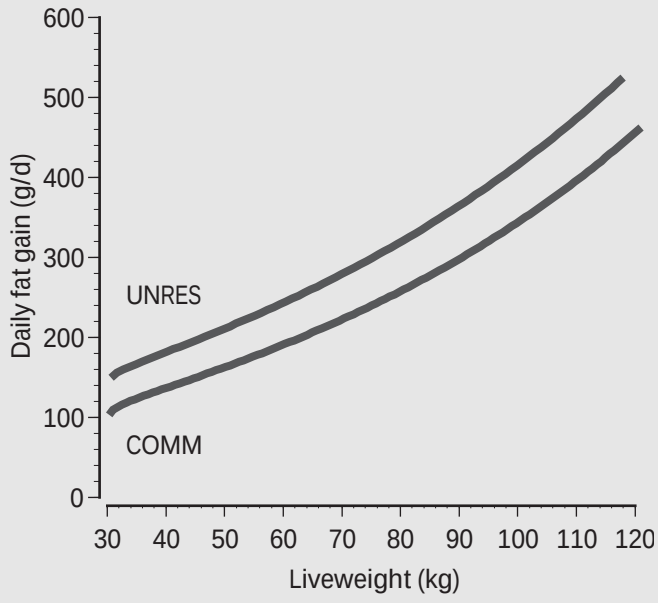
Nonlinear average daily gain

Figure 3



Nonlinear daily fat-free lean gain

Figure 4



Nonlinear daily fat gain

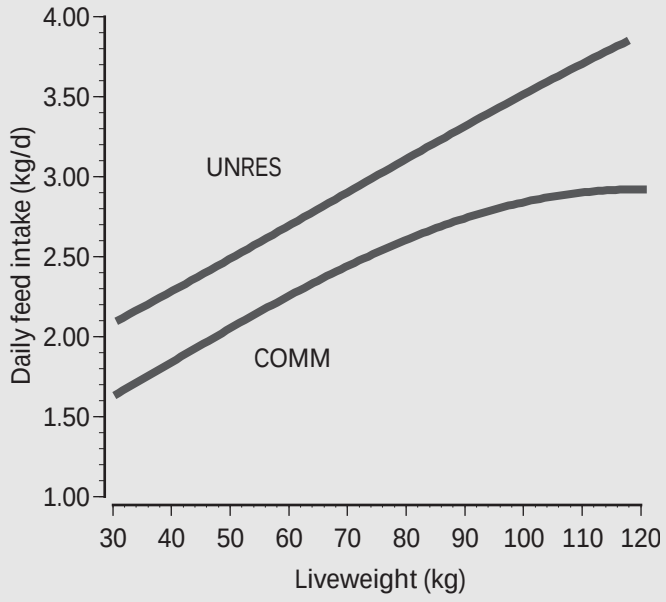
pigs immediately grew faster than COMM group pigs. The advantage in liveweight growth at each weighing was consistent throughout the finishing period.

Daily fat-free lean growth rates reached a peak at 52 kg (115 lb) liveweight in both environments and then declined (Figure 3). The rate of decline from 50 kg to 120 kg (110 lb to 265 lb) liveweight was greater for COMM group pigs (311–162 g [0.69–0.36 lb] per day) than for UNRES pigs (391–282 g [0.86–0.62 lb] per day). At 120 kg (265 lb) liveweight, the COMM pigs had achieved 52% of their maximum daily lean growth whereas the UNRES pigs had achieved 72% of their lean growth. The daily fat-free lean growth rates of the UNRES pigs were substantially greater than those of the COMM pigs up to 110 days of age (day 35 of the study). The daily lean growth of the UNRES pigs declined more rapidly with respect to age, because they achieved heavier liveweights at younger ages than the COMM pigs. Daily fat growth rates increased as liveweight increased for pigs reared in either environment (Figure 4). Daily fat growth was consistently 50–60 g (0.11–0.13 lb) per day higher for UNRES pigs than for COMM pigs.

Feed disappearance

Average daily feed disappearance was higher for the UNRES group pigs (3.0 kg [6.6 lb] per head per day) compared to the COMM group pigs (2.46 kg [5.4 lb] per head per day). Although fed the same diets, UNRES group pigs averaged 25 g (0.055 lb) lysine and 10.0 Mcal ME intake per head per day compared to 20 g (0.044 lb) lysine and 8.2 Mcal ME per head per day intake for COMM pigs. Feed disappearance differed significantly within the first 4 weeks of the study, with UNRES group pigs consuming 2.36 kg (5.2 lb) per head per day versus 1.84 kg (4.1 lb) consumed by the COMM pigs (Figure 5). Feed disappearance increased almost linearly for the UNRES group pigs with a feed

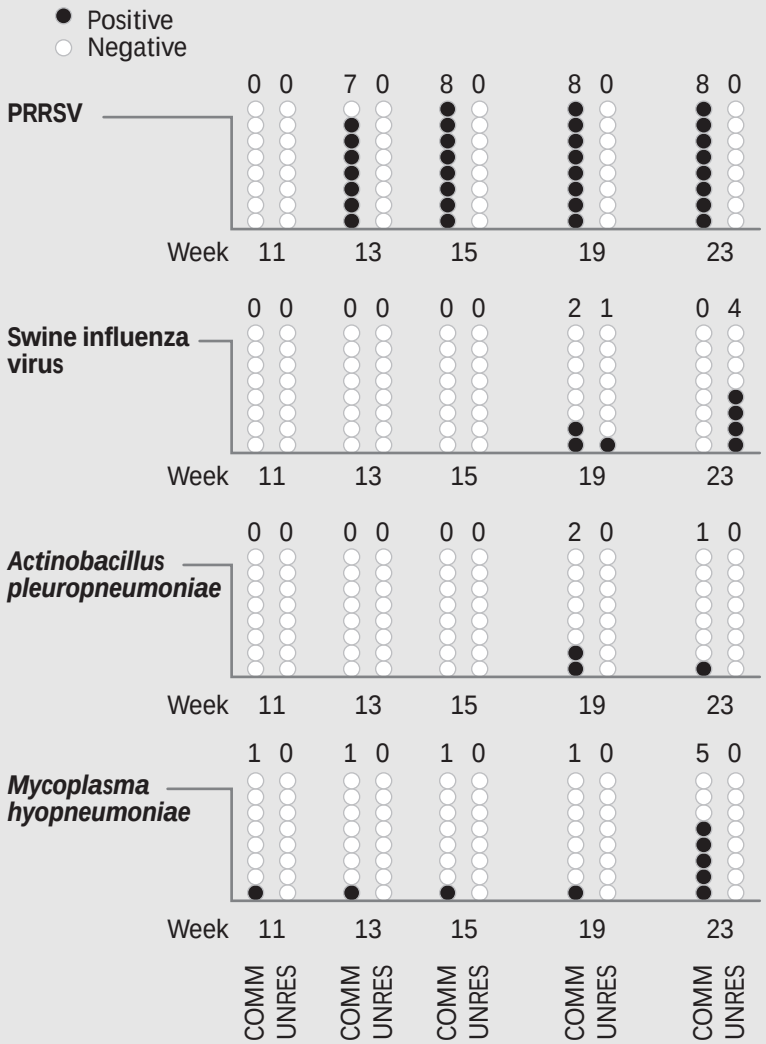
Figure 5



Nonlinear daily feed disappearance

disappearance of 3.74 kg (8.2 lb) per head per day recorded during the final 2 weeks before slaughter. The feed disappearance for the COMM group pigs was quite variable, especially in the naturally ventilated finishing building. Calculated efficiencies were 2.85 (UNRES) versus 3.29 (COMM) for feed:weight gain and 9.17 (UNRES) versus 10.44 (COMM) for feed:lean gain. These data were not statistically analyzed due to the lack of replication in the commercial environment group.

Figure 6



Serological results

Health

All pigs in the unrestricted environment appeared healthy throughout the trial and no treatments were administered. Four COMM group pigs received individual therapy during the course of the trial, two for pneumonia and two for arthritis. One pig was removed from the COMM group 4 weeks after allotment due to a severely swollen tarsal joint. All 16 pigs sampled at allotment were serologically negative for PRRSV, SIV, and *A. pleuropneumoniae* (Figure 6). One COMM group pig began the trial with a positive titer to *M. hyopneumoniae*, but was negative thereafter. COMM group pigs seroconverted to PRRSV by 13 weeks of age (seven of eight) and remained seropositive for PRRSV at subsequent bleedings. Limited seroconversion to SIV, *M. hyopneumoniae*, and *A. pleuropneumoniae* (serotype 7) was also observed in COMM group pigs. Seroconversion to SIV was also observed in the UNRES group pigs at 19 and 23 weeks of age, although no clinical disease was observed.

Differences ($P < .01$) in percentage of lung consolidation were observed at slaughter between the two groups, with mean lung lesion scores of 6.83% for COMM group pigs and 0.04% for the UNRES group pigs (Figure 7). Percent lung lesions ranged from 0%–61% for COMM group pigs while only one UNRES group pig had any lung lesions (1%). Ventral nasal turbinate space was also significantly larger ($P < .01$) for COMM group pigs (8.86 mm) than for UNRES group pigs (5.94 mm).

Biomarkers

Differences ($P < .05$) in AGP levels were detected between groups following allotment (Figure 8). While values for both groups tended to decrease over time, the values for COMM group pigs were consistently higher than those for UNRES group pigs. Haptoglobin values were not different between groups when evaluated by repeated measures after allotment (Figure 9). Haptoglobin values for the COMM pigs tended to be higher than those in UNRES pigs, except at allotment. IGF-1 values tended to be different ($P = .09$) between groups after allotment, with the largest differences between groups observed 2 and 12 weeks after allotment (Figure 10). The CD4 values were different ($P < .05$) between groups at 23 weeks of age, with higher values recorded for COMM group pigs (Figure 11). No difference was seen between groups comparing CD8 values at 23 weeks of age.

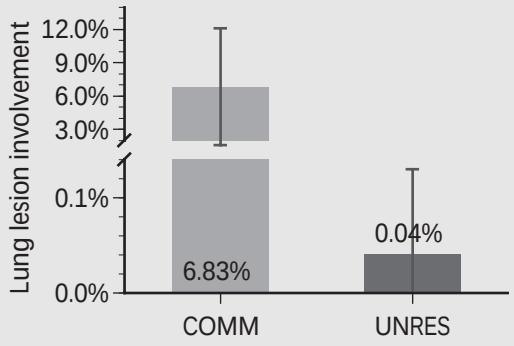
Discussion

The unrestricted environment was designed to provide nonlimiting physical (thermal, stocking density, feed and water access), social (pigs per pen, movement), and microbial (sanitation, segregation) conditions to minimize physiological and immunological stress. Growth performance of pigs raised in the UNRES environment provided an estimate of genetic potential in the grow-finish stage of production for this genotype. The significant differences in growth rates we observed between UNRES and COMM pigs are consistent with many studies in which performance differences of this magnitude were observed using segregated-early-weaning (SEW) techniques;[14,15,16] it is important to note, however, that pigs were not segregated until 11 weeks of age in the present study.

Health

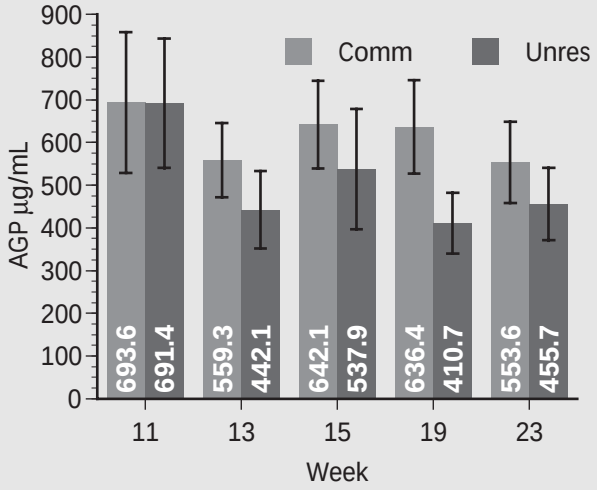
Two previous studies also documented similar differences in pig health associated with finishing environments. Straw[17] conducted a study in a herd with a high prevalence and severity of pneumonia. Pigs raised in the commercial grower/finisher (20–100 kg [44–220 lb]) had significantly reduced bodyweight gain compared to pigs raised in an improved environment (765 versus 639 g [1.7 versus 1.4 lb] per day).

Figure 7



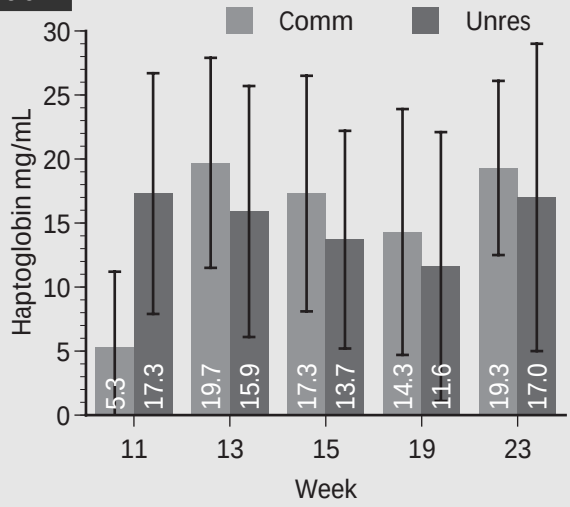
Lung lesion scores

Figure 8



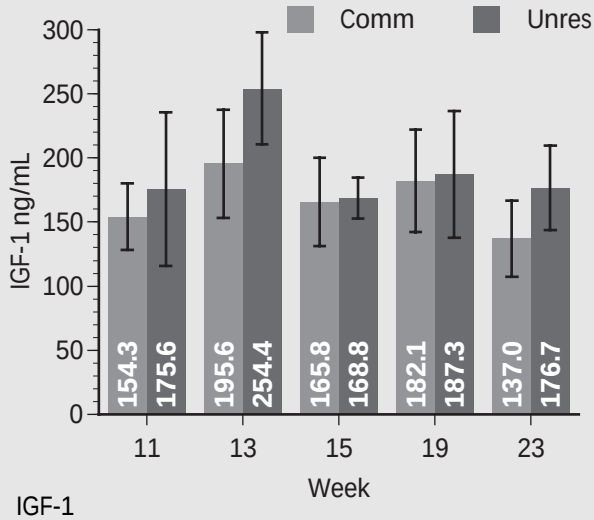
AGP

Figure 9



Haptoglobin

Figure 10



IGF-1

In contrast to our study, pneumonia lesions evaluated at slaughter did not differ between treatment groups, although the growth of pigs with severe pneumonia was significantly reduced in both environments.

Growth

Black and Carr[18] have presented data that quantifies reduced growth performance in pigs raised in commercial environments. Pigs raised from 20–87.5 kg (44–193 lb) in commercial units attained 79% of the liveweight growth realized by cohort pigs that were raised in a boar test station with greater floor area, more air space, and fewer pigs per pen. Performance was not improved when environmental conditions of the boar test-station pens were duplicated within the commercial building. They concluded that the depression in performance was associated with the conditions of the building, such as air quality, disease, social environment, and possibly interactions among these factors.

The reduction in lean or protein accretion we observed in the COMM group pigs may be associated with reduced capacity for lean deposition rather than limited intake. Chapple[19] observed the following performance differences among pigs from 20–100 kg (44–220 lb) bodyweight at different housing densities:

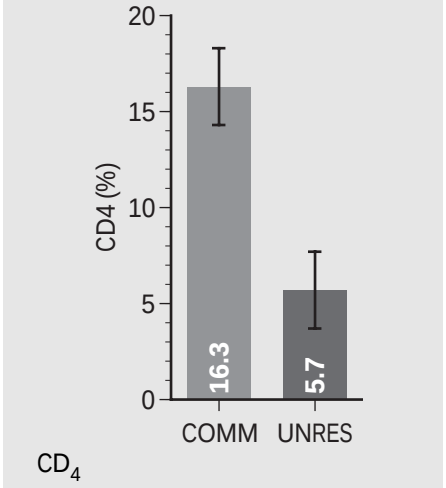
- in pigs housed alone, liveweight growth was 0.89 kg (2.0 lb) per day, predicted daily protein accretion rates were 132 g (0.29 lb) per day, backfat depth was 18.7 mm (0.74 in), and predicted fat deposition rates were 251 g (0.55 lb) per day;
- in pigs housed in groups of three, liveweight growth declined to 0.87 kg (1.9 lb) per day, and predicted daily protein accretion rates also declined to 125 g (0.28 lb) per day. P_2 backfat depth, however, increased to 20.1 mm (0.79 in), while predicted fat deposition rates remained constant at 252 g (0.56 lb) per day; and
- in pigs housed in groups of five there was a continued decline in liveweight growth (0.84 kg [1.9 lb] per day) and predicted daily protein accretion rates (119 g [0.26 lb] per day), with a noticeable increase in P_2 backfat depth to 21.7 mm (0.85 in). Predicted fat deposition rates again remained relatively unchanged at 251 g (0.55 lb) per day.

Brumm and Miller[20] concluded that the reduced gain associated with limited space was independent of lysine and energy intakes. In a series

of three experiments, they observed no interaction between space and diet density on ADG, feed efficiency (FE), or lean growth rate.

Differences in lean accretion rates observed in our study were also consistent with work by Williams, et al.,[16] in which pigs raised via age segregation had significantly higher rates of lean gain (0. 33 kg [0.73 lb] per day) compared to pigs raised in a conventional rearing system (0.24 kg [0.53 lb] per day). In contrast, the carcass fat content was similar between pigs from the two environments in our study while the conventional pigs were fatter in the Williams study. The discrepancy between the two studies may be explained by the timing of selection for slaughter (by group versus as individuals attained market weight), energy density of the diets, feed intakes, and genotypes used in the trials.

Figure 11



Our data clearly demonstrated that the COMM pigs did not achieve their lean gain potential. This could be associated with lower feed intakes although it is unlikely that intakes of 20 g (0.044 lb) lysine and 8.2 Mcal ME were limiting lean gain performance. Instead, it appears that the growth potential of the COMM group pigs was established immediately, as demonstrated by lower lean accretion compared to the UNRES group pigs. In addition, the UNRES group pigs overconsumed energy as they matured, resulting in higher fat accretion. As a consequence, the UNRES group pigs had a slightly higher fat:lean gain ratio (1.05) compared to the COMM group pigs (1.00), which resulted in a fatter carcass at slaughter. Further work evaluating a treatment group consisting of pigs reared in an unrestricted environment that are limit-fed to the intake levels measured in pigs reared in commercial environments would provide additional data to confirm lean potential and distinguish maintenance requirement differences between the two environments.

Biomarkers

Our observation that AGP concentrations in pigs from both environments tended to decrease over time, with significantly lower concentrations detected in the UNRES group pigs compared to the COMM group pigs, is consistent with the work of Itoh,[5] who found high AGP concentrations at birth that decreased with age. Itoh observed that AGP concentrations established mature baselines by 16–20 weeks of age.

Haptoglobin, which tended to be higher in the COMM pigs in our study, has been shown to be a predictor of subsequent weight gain[3] and an antemortem predictor of subclinical disease in swine.[21] There was considerable variation in haptoglobin concentrations within each group during our trial and significant difference between groups at allotment.

IGF-1 is a protein hormone that mediates many of the anabolic effects of growth hormone, but may be regulated independently of growth hormone. Our observation that IGF-1 concentrations tended to be elevated in the UNRES group pigs is consistent with previous work.[6,22,23] It is important to note, however, that mean values from pigs in both environments were similar during two of the four periods tested post allotment. Further work with limit-fed pigs in an unrestricted environment could distinguish environmental and nutrient intake influences.

Also consistent with previous work[15] was our observation that CD4 concentrations were elevated at 23 weeks of age in the COMM group pigs compared to the UNRES group pigs, while CD8 concentrations were not different. Walker, et al, detected differences in CD4 concentration between high and low immune stimulation groups of pigs from wean to market. Other recent work did not detect differences due to environment in percentages of T-lymphocytes up to 46 days postweaning, although differences were observed in CD4 and CD8 concentrations associated with age.[24]

Implications

- Liveweight, lean, and fat growth in pigs raised in a conventional commercial environment was reduced to 70% of that achieved under less limiting research conditions. This reduction was likely associated with reduced capacity for growth rather than limited nutrient intake.
- The unrestricted environment resulted in fatter carcasses at slaughter; therefore, energy intake must be monitored closely in high-health herds to minimize excess fat accretion.
- Differences in AGP and CD4 concentrations between environments were detected, suggesting their potential use as biomarkers. There was also a trend toward differences in IGF-1 between environments.
- This model could be used to estimate the impact of the commercial environment on growth performance in swine production systems, specific to genotype and environment.
- The results of this trial suggest that additional research is needed to understand the environmental factors limiting pig growth and evaluate cost effective methods of intervention.

Acknowledgments

We would like to acknowledge the generous contributions of Dr. Kevan Flaming (statistical assistance), Elanco Animal Health (funding), BI/NOBL Laboratories (AGP kits), Bayer/Oxford Laboratories (serology), Dr. Michael Spurlock (haptoglobin assays), Akey Feeds (premix), Fearing Inc. (eartags), Iowa State University College of Veterinary Medicine (facilities), Dr. Steve Menke (slaughter plant arrangements), and Mr. Ron Dean (producer).

References

1. DiPietre D, Tubbs R. Current measures of production efficiency. *Proc NPPC Pork Profitability Summit, Des Moines, Iowa*. 1995; 8–30.

2. Schinckel AP. *Executive Veterinary Program*, Swine Health Management, University of Illinois. December 1994.

3. Eurell TE, Bane DP, Hall WF, Schaeffer DS. Serum haptoglobin concentration as an indicator of weight gain in pigs. *Can J Vet Res*. 1992;56:6–9.

4. Francisco CJ, Bane DP, Weigel RM, Unversagt L. The influence of pen density, weaning age, and feeder space on serum haptoglobin concentration in young growing swine. *SHAP*. 1996;4(3):67–71.

5. Itoh H, Tamura K, Izumi M, Motoi Y, Kidoguchi K, Funayama Y. The influence of age and health status on serum alpha-acid glycoprotein level of conventional and specific pathogen-free pigs. *Can J Vet Res*. 1992;57:74–78.

6. Taylor JA, Salter DN, Close WH, Laswai GH. Serum concentrations of insulin-like growth factor 1 and cholesterol in relation to protein and fat deposition in growing pigs. *Anim Prod*. 1992;55:257–264.

7. Pointon AM, Mercy AR, Backstrom L, Dial GD. Disease surveillance at slaughter. *Diseases of Swine, 7th Edition*. 1992;968–987.

8. Buonomo FC, Grohs DL, Baile CA, Campion DR. Determination of circulating levels of insulin-like growth factor II (IGF-II) in swine. *Dom Anim Endocrinol*. 1988;5:323–329.

9. Dahl GE, Chapin LT, Zinn SA, Moseley WM, Schwartz TR, Tucker HA. Sixty-day infusions of somatomedin-releasing factor stimulate milk production in dairy cows. *J Dairy Sci*. 1990;73:2444–2452.

10. Schinckel AP. Method to predict body component growth curves. *Proc NC204 Swine Growth Modeling Regional Committee*. 1995.

11. Bridges TC, Turner UW, Smith EM, Stahly TS, Loewer OJ. A mathematical procedure for estimating animal growth and body composition. *Trans Am Soc Ag Eng*. 1986;29:1342–1347.

12. Schinckel AP, de Lange CFM. Characterization of growth parameters needed as inputs for pig growth models. *J Anim Sci*. 1996;74:2021–2036.

13. Whittemore CT, Tullis JB, Emmans GC. Protein growth in pigs. *Anim Prod*. 1988;46:437–445.

14. Schinckel AP, Clark LK, Stevenson G, Knox KE, Nielsen J, Grant AL, Hancock DL, Turek J. Effects of antigenic challenge on growth and composition of segregated early-weaned pigs. *SHAP*. 1995;3(6):228–234.

15. Walker R, Wiseman BA. Comparison of off-site early weaned and conventionally weaned pigs from weaning to market. *Recent Advances in Swine Production and Health*. St. Paul, Minnesota: University of Minnesota Swine Center. 1993;3:10–17.

16. Williams NH, Stahly TS, Zimmerman DR. Impact of immune system activation on growth and amino acid needs of pigs from 6 to 114 kg body weight. *J Anim Sci*. 1994;72(suppl 2):57.

17. Straw BE. Performance measured in pigs with pneumonia and housed in different environments. *JAVMA*. 1991;198:627–630.

18. Black JL, Carr JR. A symposium - stocking density and pig performance. *Manipulating Pig Production IV*. Proc. First Biennial Conf Aust Pig Vet Soci, Canberra, Australia. 1993:84.

19. Chapple RP. Effect of stocking arrangement on pig performance. *Manipulating Pig Production IV*. Proc. First Biennial Conf Aust Pig Vet Soci, Canberra, Australia. 1993:87–97.

20. Brumm MC, Miller PS. Response of pigs to space allocation and diets varying in nutrient density. *J Anim Sci*. 1996;74:2730–2737.

21. Bane DP, Funk JA, Neumann EJ, Ackermann MA. Correlation of serum acute phase proteins with gross pathology in market swine. *IPVS Proc*. 1994:426.

22. Clutter AC, Spicer LJ, Woltmann MD, Grimes RW, Hammond JM, Buchanan DS. Plasma growth hormone, insulin-like growth factor 1, and insulin-like growth factor binding proteins in pigs with divergent genetic merit for postweaning average daily gain. *J Anim Sci*. 1995;73:1776–1783.

23. Lamberson WR, Safranski TJ, Bates RO, Keisler DH, Matteri RL. Relationships of serum insulin like growth factor 1 concentrations to growth, composition, and reproductive traits of swine. *J Anim Sci*. 1995;73:3241–3245.

24. Fangman TJ, Tubbs RC, Becker BA, Allee GL, Misfeldt ML, Henningsen-Dyer K. Evaluation of segregated early weaning investigating performance, immunologic indicators (CD4, CD8), and herd health status. *SHAP*. 1997;4(5):217–222.