The Effect of Rearing Environment on Two Ractopamine Use Programs

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Introduction

The beta-adrenergic agonist ractopamine (RAC) is a feed additive used to increase lean growth rate, improve feed efficiency, and increase carcass lean percentage and dressing percentage (Moody et al., 2000). Health status of the individual pig can influence and determine the amount of lean tissue growth of the pig (Holck et al., 1998), especially during a time of rapid growth such as in response to ractopamine.

Williams et al. (1997) reported that high health pigs consumed more feed, gained body weight faster, and produced bodies with more muscle and less fatty tissue than low health pigs. Since the level of disease pressure in swine facilities plays a major role in determining the growth rate of pigs in a particular environment, the objective of this study was to determine whether environmental health conditions affect the growth response of pigs fed ractopamine.

Materials and Methods

Experimental design. Ninety-three littermate barrows and 96 littermate gilts were weaned into an SEW nursery, and following the nursery period, were randomly allotted into 48 pens (4 pigs/pen; 10.8-12.9 ft2/pig) of two barns with distinctly different environments for the duration of the grow/finish phases (45 lb to market BW). One barn type was an all-in, all-out facility (AIAO) with high bio-security measures in place. The second environment housed pigs in a continuous flow facility (CF) that contained pigs of various ages without being thoroughly cleaned and disinfected between groups of pigs. At an average initial body weight of 159.0 lb, each pen was randomly assigned to one of three dietary sequences, resulting in a 2 x 2 x 3 factorial arrangement of environment, sex, and dietary treatments over four weight blocks.

Ractopamine use programs. Two ractopamine use programs and a control diet were fed ad libitum through the last six weeks prior to market weight and slaughter. Ractopamine dietary treatments were as follows: 1) Control: no ractopamine; 2) Step-up: 4.5 g/ton (5 ppm) RAC weeks 0-3 and 9.0 g/ton (10 ppm) RAC weeks 4-6; 3) Constant: 9.0 g/ton (10 ppm) RAC weeks 0-6. Diets were formulated to meet or exceed NRC (1998) requirements for all nutrients (Table 1). Barrows were fed a 19.0% CP diet with 1.05% lysine the first three weeks and then an 18.3% CP diet with 1.00% lysine the last three weeks. The gilts consumed a 20.5% CP, 1.15% lysine diet the first three weeks and then a 19.8% CP, 1.10% lysine diet the last three weeks. Swine yellow grease was added to all diets at a 5% inclusion rate. Corn was removed from the basal diet and replaced with ractopamine to create the ractopamine sequences. During the last three weeks of the study, Tylosin at 100 g/ton was fed in the diets.

Growth performance. The pigs were weighed and feed intake was recorded weekly through d 42 to determine average daily gain (ADG), average daily feed intake (ADFI), and feed efficiency. In addition, three pigs/pen (48/treatment) were serially scanned using real-time ultrasound on d 0, 21, and 42 to measure loin eye area (LEA) at the tenth rib, and off-midline tenth rib and last rib backfat thickness. Additionally, pigs showing clinical signs of disease were treated with injectable antibiotics and the treatments recorded.

Carcass characteristics. After six weeks on test, the pigs were taken to a commercial pork processing facility where individual hot carcass weights, ultrasonic loin and backfat depth measurements, and predicted percent lean values were collected by the processor. A minimum market weight was set at 220 lb.

Plasma collection and analysis. Blood plasma samples were harvested via jugular venipuncture from three pigs/pen (48/treatment) on d 0, 14, 28, and 42. The same pigs were bled at each time point, and were the same pigs from which ultrasonic measurements were collected. All pigs were aroused at 0600 h and allowed to consume feed until 0700 h, at which time the feeders were removed. Bleeding of pigs commenced at 0900 h. Blood was collected in two heparinized tubes, placed on ice immediately, centrifuged, divided into four 1.5 mL aliquots, and stored at -20 ºC until analyses were performed. Plasma concentrations of insulin-like growth factor-I (IGF-I) and growth hormone (GH) were quantified via double antibody radioimmunoassay (RIA) procedures. Plasma antibodies to porcine reproductive and respiratory syndrome (PRRS) and *Mycoplasma hyopneumoniae* (*M. hyo*) were determined via enzyme-linked immunosorbent assays (ELISA) performed by the serology department of the Purdue University Animal Disease and Diagnostic Laboratory. Plasma antibodies to swine influenza virus (SIV) were determined by hemagglutination inhibition (HI) completed by the serology department of the Iowa State University Veterinary Diagnostic Laboratory.

Body component accretion curves. Growth and body composition curves were generated using similar procedures to those outlined by Schinckel et al. (2002). Live weight data were best fit to age using a linear/quadratic equation ($WT = b0 + (b1*T) + (b2*T2)$) where WT equals body weight minus birth weight (3.3 lb) and T is days on test. The regression procedure of SAS (PROC REG; SAS Inst. Inc., Cary, NC, 2000) was used to fit this function. A series of prediction equations using live weight, off midline ultrasonic tenth rib and last rib backfat depths, and longissimus muscle area data were used to estimate the content of several body components. To generate the carcass trait curves, exponential functions were used to express fat-free total lean and empty body protein, while augmented allometric functions were fit for total carcass fat and empty body lipid deposition.

Statistical analysis. Pen was the experimental unit for the growth performance and predicted body composition and tissue accretion data, while individual pig was the experimental unit for the carcass measurements, real-time ultrasound data, and plasma data. Data analysis was performed with dietary treatment, sex, and environment as the main effects along with their interaction using the general linear models procedure of SAS (PROC GLM; SAS Inst. Inc., Cary, NC, 2000). Plasma antibody data were analyzed using the FREQ procedure of SAS (SAS Inst. Inc., Cary, NC, 2000) to calculate the Chi-square of the proportions of seropositive pigs. The GH and IGF-1 data were analyzed as repeated measures over time using the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC, 2000). All means are reported as least square means and separated using a probability of difference at $P < 0.05$.

Results

Ractopamine Effects

Growth performance. By d 42, pigs fed the RAC step-up averaged final body weights that were 10.9 lb heavier ($P < 0.05$) than the control pigs and 6.8 lb heavier ($P < 0.05$) than the pigs fed the constant rate program (Table 2). Pigs fed ractopamine averaged 17.8% greater ADG ($P < 0.05$) and 13.7% lower feed:gain ratio($P < 0.05$) than the control pigs during weeks 0-3. Over the last three weeks pigs fed the step-up program had 11.2% greater ADG ($P < 0.05$) than pigs on the constant rate even though both consumed 9.0 g/ton RAC diets during those three weeks. In addition, the pigs fed the step-up program had a 7.5% improvement in feed:gain ratio ($P < 0.05$) compared to both the control and constant rate fed pigs, while pigs fed the constant rate program had a 0.44 lb/d lower ADFI ($P < 0.05$) than the control pigs with the step-up fed pigs being intermediate during wk 4-6. For the entire six-week period, pigs fed ractopamine had 9.9% greater ADG ($P < 0.05$) and 10.6% improved feed:gain ratio ($P < 0.05$) compared to the control pigs. Pigs fed the RAC step-up program had overall ADG that was 13.5% greater than the control fed pigs ($P < 0.05$) and 6.9% greater than the constant rate fed pigs ($P < 0.05$). The pigs fed the constant rate program had 5.1% lower ADFI ($P < 0.05$) than the step-up fed pigs while the control pigs were intermediate throughout the six-week feeding period.

Initially, no significant differences among treatments were found in last rib backfat depths LEA (Table 3), but the pigs fed the constant rate program did start with tenth rib backfat depths that were 0.04 in. less than the control pigs ($P < 0.05$) while the step-up pigs were intermediate. By d 42, pigs fed ractopamine had 8.8% less tenth rib backfat ($P < 0.05$) than the control pigs. Pigs fed the constant rate program also had less last rib backfat ($P < 0.05$) than the control pigs. On the basis of change in backfat depth from d 0 to 42, only the pigs fed the step-up program had a significant reduction in tenth rib backfat deposition (19.2%) compared to the control pigs, while only the pigs fed the constant rate program had a significant reduction in last rib backfat deposition (33.3%) compared to the control pigs. Additionally, pigs fed ractopamine had a 7.3% larger ultrasonic LEA ($P < 0.05$) than the control pigs on d 42. Likewise, on a change basis, pigs fed the step-up program averaged a 27.8% greater increase in LEA ($P < 0.05$) compared to the pigs fed the control diet, while pigs fed the constant rate program averaged a 37.7% greater increase in LEA ($P < 0.05$) compared to the control pigs.

Carcass characteristics. The percentage of the pigs/pen that were not marketed after the six-week time frame was calculated and nearly 11% fewer pigs fed the constant rate program reached target market weight (220 lb) as compared to the pigs fed the step-up program ($P < 0.05$), while the control treatment was intermediate in the number of light pigs per pen (Table 4). At slaughter, body weights and hot carcass weights of pigs fed ractopamine were on average 7.75 lb heavier ($P < 0.05$) than the control pigs. Pigs fed the constant rate program had about 0.07 in. less backfat ($P < 0.05$) along with numerically increased loin depths, resulting in a 0.76 percentage unit increase in processor predicted percent lean ($P < 0.05$) as compared to the control pigs. Pigs fed the step-up program had fat depths, loin depths, and percent lean values that were between and not different from those of the constant rate or control fed pigs. No significant difference in dressing percent was found among ractopamine programs. As a result, the pigs fed the constant rate program had a $1.05/cwt increase in carcass grade premiums ($P < 0.05$) compared to pigs fed the control diet, while pigs fed the step-up program were intermediate. However, due to the heavier carcass weights and increased grade premiums, all pigs fed ractopamine resulted in a higher total value per pig ($P < 0.05$) than those pigs fed the control diet ($105.18 vs. $99.45).

Predicted body component accretion. There were no significant differences in body composition among ractopamine programs at the start of the trial (Table 5). At the conclusion of the study, all pigs fed ractopamine averaged 6.0 lb more predicted fat-free total lean tissue (P < 0.05) than pigs fed the control diet. No significant differences among ractopamine programs were projected for total carcass fat (P > 0.05) throughout the six weeks of the study. Overall, for weeks 0-6, pigs fed ractopamine had a 21.0% increase in predicted fat-free lean gain (P < 0.05) compared to the pigs fed the control diet. Also, pigs fed the step-up program had a 9.9% increase in total carcass fat accretion (P < 0.05) compared to the pigs fed the control diet while the constant rate ractopamine fed pigs were intermediate.

Disease exposure. The proportion of pigs testing positive for plasma antibodies to *Mycoplasma hyopneumoniae*, PRRS virus, and swine influenza virus did not vary (P > 0.20) among ractopamine programs (Table 6).

Plasma hormone levels. Overall, plasma GH and IGF-I concentrations were not affected (P > 0.45) by either ractopamine use program and did not differ significantly from the control pigs (Table 7). A strong time effect was present (P < 0.001). GH levels in all pigs rose and then decreased over the study while IGF-I levels tended to rise over time. No interactions between ractopamine programs and environment were found for GH concentration, but a RAC x ENV interaction existed for IGF-I levels (P < 0.008). In the AIAO environment, IGF-I levels in all pigs increased over time, but in the CF environment, IGF-I levels in pigs fed ractopamine remained relatively constant over time while the IGF-I levels of the control pigs in the CF environment increased over time.

<u>Environmental Effects</u>

Growth performance. Pigs in the AIAO environment started on test at an average age of 123 d, whereas pigs in the CF environment started on test at an average age of 133 d to meet the initial starting body weight. Pigs in the CF environment had initial body weights that were on average 2.7 lb heavier (P < 0.001) than the pigs in the AIAO environment (Table 2). By d 21, body weights were nearly identical between environments (P > 0.05), and on d 42 pigs in the AIAO environment had 1.3 lb heavier final body weights than the pigs in the CF environment. During weeks 1-3 of the study, pigs in the AIAO environment had 6.3% greater ADG (P < 0.06) with a 9.3% increase in ADFI (P < 0.001) compared to the pigs in the CF environment. Conversely, ADG and ADFI did not differ (P > 0.05) between environments through the last three weeks of the study. Overall, pigs in the AIAO environment tended to have 4.0% greater ADG (P < 0.09) with a 3.4% increase in ADFI (P < 0.07). Feed:gain ratio did not differ between environments (P > 0.63) during the entire study.

Initially, pigs in the CF environment began the study with 8.0% greater tenth rib (P < 0.01) and 5.9% greater last rib (P < 0.07) backfat depths as well as 0.17 in^2 smaller LEA (P < 0.04) as compared to the pigs in the AIAO environment (Table 3). However, by d 42 the pigs in the AIAO environment ended with slightly increased tenth rib and last rib backfat depths (P > 0.05) resulting from a 35.0% greater change in backfat deposition (P < 0.001) during the entire trial as compared to the pigs in the CF environment. Pigs in both environments had similar LEA (P > 0.05) at d 42, with nearly identical changes in LEA from d 0 to 42.

Carcass characteristics. The percent of the pen that was not marketed after the six-week time frame was significantly greater (P < 0.04) in the CF environment (Table 4); an average of about 7% more pigs failed to reach market weight in the CF environment as compared to the AIAO environment. Since the smaller pigs were not marketed, final slaughter weights and hot carcass weights of pigs in the CF environment were on average 13.1 lb and 8.8 lb heavier (P < 0.01) than the pigs in the AIAO environment. Contrary to the ultrasonically measured data, processor measurements indicated that the pigs in the CF environment had 0.13 in. greater fat depths ($P < 0.05$) compared to the pigs in the AIAO environment. Loin depths were numerically increased in the pigs in the AIAO environment compared to the pigs in the CF environment, in agreement with the ultrasonically measured LEA data. The processor determined percent lean values indicate that the pigs in the AIAO environment had a 1.2 percentage unit greater predicted percent lean ($P < 0.04$) as well as a trend for a 1.2 percentage unit increase in dressing percentage ($P < 0.06$) as compared to the pigs in the CF environment. No significant differences were found in carcass grade premiums or total value per pig between the two environments.

Predicted body component accretion. There were no significant differences in fat-free total lean mass between environments at the start of the trial (Table 5). However, pigs housed in the CF environment began the study with 4.6% more total carcass fat ($P < 0.005$) than the pigs in the AIAO environment. During the first half of the study pigs housed in the CF environment averaged 43.5% greater total carcass fat accretion rates ($P < 0.001$) compared to the pigs in the AIAO environment, but conversely, over the last three weeks, pigs in the AIAO environment averaged 25.5% greater total carcass fat accretion rates ($P < 0.001$) compared to the pigs in the CF environment. Overall from d 0 to 42, no significant differences ($P > 0.05$) were predicted for body composition or tissue accretion rates between environments.

Disease exposure. The proportion of pigs testing positive for plasma antibodies to *Mycoplasma hyopneumoniae*, PRRS virus, and swine influenza virus were clearly different ($P < 0.001$) between rearing environments (Table 6). The CF environment had nearly 90% more pigs seropositive for *M. hyo* and PRRS and almost 30% more pigs seropositive for SIV compared to the AIAO environment. Additionally, about 90% more pigs in the CF environment required therapeutic treatment with injectable antibiotics at least once throughout the study compared to the AIAO environment.

Plasma hormone levels. Overall, plasma GH concentrations did not differ ($P > 0.11$) between pigs in the two environments (Table 7). However, pigs housed in the AIAO environment had significantly greater plasma IGF-I concentrations (120.75 vs. 112.16 ng/mL; $P < 0.031$) compared to the CF environment.

Discussion

The AIAO environment in this study was considered to provide optimal growing conditions with minimal disease exposure due to its segregation from non-contemporary animals and bio-security measures. The CF environment, on the other hand, was expected to contain less than optimal growing conditions with a greater disease load present due to the constant trafficking of animals of various stages of maturity in and out of the facility. Serological tests helped to quantify these differences in disease pressures between facilities.

Overall growth rate in the late finishing phase tended to be slower for the pigs housed in the CF environment as compared to the pigs in the AIAO environment. Due to the differences in growth rate during the grower phase prior to this study, the number of days to market for the pigs was at least 10 days less for the pigs in the AIAO environment compared to the pigs in the CF environment. Also, fewer pigs failed to reach market weight after six weeks on test as compared to the pigs in the CF environment and there were fewer pigs requiring therapeutic antibiotic treatments in the AIAO environment compared to the CF environment.

The overall response to ractopamine did not differ between environments. Among ractopamine programs, pigs fed the ractopamine step-up program were found to have increased overall ADG (13.5%) and feed efficiency (11.4%) compared to pigs fed the control treatment, while the constant 9 g/ton RAC fed pigs only had a 6.3% increase in ADG and 9.8% increase in feed efficiency over the control pigs. Over the first three weeks of this study, the ractopamine growth response to both 4.5 g/ton and 9 g/ton RAC began to decline, but over the final three weeks, the growth response was sustained by the step-up program (11.2% greater ADG and 5.6% greater feed efficiency) as compared to the constant rate ractopamine program. Thus, the ractopamine step-up program was effective in enhancing the duration and magnitude of the ractopamine growth response in both environments.

Implications

Both ractopamine programs improved pig growth rate, feed efficiency, and carcass characteristics equally well in either environment. Specifically, the 3 week-3 week ractopamine step-up program with levels of 4.5 g/ton and 9 g/ton, respectively, had the greatest increase in body weight and rate of gain and provides a more effective ractopamine use program that will maximize pig performance while feeding ractopamine in either environmental health condition.

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Table 1. Ingredient, calculated, and analyzed composition of experimental diets, as -is basis

	Barrows					Gilts				
Ractopamine, g/ton	**0**	**4.5**	**9.0**	**0**	**9.0**	**0**	**4.5**	**9.0**	**0**	**9.0**
	Weeks 0-3			**Weeks 4-6**		**Weeks 0-3**			**Weeks 4-6**	
Ingredient, %										
Corn	64.685	64.660	64.635	66.390	66.340	61.005	60.980	60.955	62.720	62.670
Soybean meal, 48% CP	27.710	27.710	27.710	25.850	25.850	31.440	31.440	31.440	29.570	29.570
Swine Yellow Grease	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000
Dicalcium Phosphate	1.020	1.020	1.020	1.060	1.060	0.950	0.950	0.950	0.990	0.990
Limestone	0.910	0.910	0.910	0.900	0.900	0.930	0.930	0.930	0.920	0.920
Salt	0.250	0.250	0.250	0.250	0.250	0.250	0.250	0.250	0.250	0.250
Vitamin Premix[a]	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150
Trace Mineral Premix[b]	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125
Lysine – HCl	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
Microaid	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050
Tylan-40	0.000	0.000	0.000	0.125	0.125	0.000	0.000	0.000	0.125	0.125
Paylean-9	0.000	0.025	0.050	0.000	0.050	0.000	0.025	0.050	0.000	0.050
Calculated Composition										
ME, Kcal/lb	1604	1604	1604	1604	1604	1604	1604	1604	1604	1604
Crude protein, %	19.01	19.01	19.01	18.26	18.26	20.51	20.51	20.51	19.76	19.76
Crude fat, %	7.53	7.53	7.53	7.58	7.58	7.43	7.43	7.43	7.48	7.48
Lysine, %	1.05	1.05	1.05	1.00	1.00	1.15	1.15	1.15	1.10	1.10
Ca, %	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65
P, %	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55
Analyzed Composition										
Crude protein, %	18.47	18.54	18.66	18.18	18.42	20.10	19.58	20.47	19.44	20.12
Lysine, %	1.08	1.11	1.10	1.06	1.06	1.23	1.14	1.27	1.12	1.22
Crude Fat, %	6.91	7.14	7.21	7.41	7.74	7.47	7.89	7.32	7.47	7.77
Ractopamine, g/ton	< 2.3	4.1	7.6	< 2.3	8.1	< 2.3	3.6	8.4	< 2.3	7.5

[a] Supplied the following per lb of diet: 1650 IU Vitamin A, 165 IU Vitamin D_3, 12 IU Vitamin E, 9.53 µg Vitamin B_{12}, 0.54 mg Menadione, 1.93 mg Riboflavin, 5.99 mg d-Pantothenic Acid, 8.98 mg Niacin.

[b] Supplied the following per ton of diet: 8.2 g/ton Cu, 0.334 g/ton I, 88 g/ton Fe, 10.9 g/ton Mn, 88 g/ton Zn, 540 g/ton Se.

Table 2. The effect of ractopamine use programs, sex, or environmental health conditions on BW, ADG, ADFI, and feed efficiency in late finishing pigs

	Ractopamine Program			Std. Error[e]	Sex		Environment		Std. Error[g]	Significance, P <		
	Control[d]	Step-up[d]	Constant[d]		Barrows	Gilts	AIAO[f]	CF[f]		RAC	SEX	ENV
Number of pigs	63	63	63		93	96	96	93				
Initial BW, lb	159.5	158.6	158.6	0.48	159.6	158.3	157.6	160.3	0.39	0.312	0.020	0.001
d 21 BW, lb	199.7[b]	206.8[a]	205.1[a]	1.28	205.9	201.8	204.0	203.7	1.05	0.001	0.008	0.843
Final BW, lb	240.3[b]	251.2[a]	244.4[b]	1.69	247.9	242.7	245.9	244.6	1.38	0.001	0.012	0.526
Weeks 0-3												
ADG, lb/d	1.91[b]	2.29[a]	2.21[a]	0.06	2.21	2.07	2.21	2.07	0.05	0.001	0.065	0.051
ADFI, lb/d	5.33	5.60	5.30	0.12	5.80	5.02	5.65	5.17	0.09	0.147	0.001	0.001
Feed:Gain	2.81[b]	2.44[a]	2.41[a]	0.06	2.67	2.44	2.58	2.53	0.05	0.001	0.001	0.526
Weeks 4-6												
ADG, lb/d	1.93[ab]	2.08[a]	1.87[b]	0.05	2.00	1.92	1.97	1.95	0.04	0.023	0.211	0.733
ADFI, lb/d	6.06[a]	5.89[ab]	5.62[b]	0.11	6.13	5.58	5.80	5.91	0.09	0.029	0.001	0.428
Feed:Gain	3.14[b]	2.85[a]	3.02[b]	0.05	3.09	2.92	2.96	3.05	0.044	0.002	0.009	0.176
Overall												
ADG, lb/d	1.92[c]	2.18[a]	2.04[b]	0.04	2.10	2.00	2.09	2.01	0.03	0.001	0.029	0.087
ADFI, lb/d	5.70[ab]	5.75[a]	5.46[b]	0.09	5.97	5.30	5.73	5.54	0.07	0.050	0.001	0.063
Feed:Gain	2.97[b]	2.63[a]	2.68[a]	0.04	2.86	2.66	2.75	2.77	0.03	0.001	0.001	0.625

[a,b,c] Within a row, ractopamine program means without a common superscript letter differ ($P < 0.05$).
[d] Control: no RAC; Step-up: 4.5 g/ton RAC wk 0-3, 9.0 g/ton RAC wk 4-6; Constant: 9.0 g/ton RAC wk 0-6.
[e] Pooled standard error of ractopamine program means.
[f] AIAO: All-in, all-out environment; CF: Continuous flow environment.
[g] Pooled standard error of sex and environment means.

Table 3. The effect of ractopamine use programs, sex, or environmental health conditions on ultrasonic measurements of backfat and loin eye area in late finishing pigs

	Ractopamine Program			Std.	Sex		Environment		Std.	Significance, P <		
	Control[c]	Step-up[c]	Constant[c]	Error[d]	Barrows	Gilts	AIAO[e]	CF[e]	Error[f]	RAC	SEX	ENV
Number of pigs	48	48	48		72	72	72	72				
Initial BW, lb	160.4	159.0	159.4	0.93	160.1	159.1	158.6	160.6	0.76	0.546	0.384	0.053
Day 0												
10^{th} Rib BF, in	0.54[a]	0.52[ab]	0.50[b]	0.01	0.55	0.48	0.50	0.54	0.01	0.053	0.001	0.004
Last Rib BF, in	0.53	0.53	0.52	0.01	0.55	0.50	0.51	0.54	0.01	0.591	0.001	0.072
Loin Eye Area, in^2 [g]	5.13	5.17	5.04	0.07	5.03	5.19	5.20	5.03	0.06	0.413	0.057	0.037
Day 21												
10^{th} Rib BF, in	0.66	0.66	0.62	0.02	0.71	0.58	0.63	0.67	0.01	0.183	0.001	0.031
Last Rib BF, in	0.61	0.62	0.59	0.01	0.66	0.56	0.58	0.63	0.01	0.280	0.001	0.004
Loin Eye Area, in^2	6.02[b]	6.36[a]	6.37[a]	0.08	6.08	6.41	6.42	6.07	0.07	0.005	0.001	0.001
Day 42												
10^{th} Rib BF, in	0.80[a]	0.73[b]	0.73[b]	0.02	0.84	0.67	0.77	0.74	0.02	0.026	0.001	0.322
Last Rib BF, in	0.68[a]	0.66[ab]	0.62[b]	0.08	0.71	0.60	0.66	0.65	0.01	0.025	0.001	0.728
Loin Eye Area, in^2	6.63[b]	7.10[a]	7.13[a]	0.11	6.83	7.07	7.03	6.87	0.09	0.002	0.059	0.213
Overall Change												
10^{th} Rib BF, in	0.26[a]	0.21[b]	0.23[ab]	0.02	0.29	0.19	0.27	0.20	0.02	0.133	0.001	0.001
Last Rib BF, in	0.15[a]	0.13[ab]	0.10[b]	0.02	0.16	0.10	0.14	0.11	0.01	0.048	0.001	0.069
Loin Eye Area, in^2 [g]	1.51[b]	1.93[a]	2.08[a]	0.11	1.80	1.88	1.83	1.85	0.09	0.001	0.516	0.889
Final BW, lb	241.2[b]	250.5[a]	247.5[a]	2.10	247.7	245.1	245.4	247.4	1.72	0.007	0.288	0.406

[a,b] Within a row, ractopamine program means without a common superscript letter differ ($P < 0.05$).
[c] Control: no RAC; Step-up: 4.5 g/ton RAC wk 0-3, 9.0 g/ton RAC wk 4-6; Constant: 9.0 g/ton RAC wk 0-6.
[d] Pooled standard error of ractopamine program means.
[e] AIAO: All-in, all-out environment; CF: Continuous flow environment.
[f] Pooled standard error of sex and environment means.
[g] SEX x ENV interaction ($P < 0.02$).

Table 4. The effect of ractopamine use programs, sex, or environmental health conditions on carcass characteristics of late finishing pigs

	Ractopamine Program			Std. Error[d]	Sex		Environment		Std. Error[f]	Significance, P <		
	Control[c]	Step-up[c]	Constant[c]		Barrows	Gilts	AIAO[e]	CF[e]		RAC	SEX	ENV
Number of pigs	59	62	55		88	88	93	83				
% Light pigs/pen[g]	6.25[ab]	1.56[b]	12.50[a]	0.03	5.21	8.33	3.13	10.42	0.02	0.046	0.372	0.042
Slaughter Wt, lb	240.8[b]	249.1[a]	248.0[a]	1.87	248.6	243.3	239.4	252.5	1.95	0.001	0.008	0.001
Hot Carcass Wt, lb	184.5[b]	192.5[a]	192.4[a]	1.56	190.7	188.8	185.4	194.2	1.62	0.001	0.254	0.008
Fat Depth, in[h,i]	0.79[a]	0.79[ab]	0.72[b]	0.03	0.83	0.70	0.70	0.83	0.03	0.086	0.001	0.042
Loin Depth, in[h,i]	2.72	2.74	2.79	0.03	2.70	2.80	2.80	2.70	0.03	0.303	0.005	0.142
Predicted % Lean[h,i]	54.82[b]	54.95[ab]	55.58[a]	0.27	54.48	55.75	55.72	54.51	0.28	0.086	0.001	0.037
Dressing Percent[h]	77.17	77.21	77.47	0.29	76.79	77.77	77.87	76.69	0.30	0.697	0.001	0.054
Base Price, $/cwt	48.52	48.58	48.55	0.07	48.50	48.60	48.63	48.48	0.07	0.800	0.191	0.310
Carcass Grade Premium, $/cwt	5.33[a]	5.71[ab]	6.38[b]	0.34	5.35	6.27	6.24	5.37	0.36	0.068	0.014	0.232
Total Value, $/pig	99.45[b]	104.56[a]	105.81[a]	1.25	102.84	103.71	101.80	104.75	1.30	0.003	0.511	0.263

[a,b] Within a row, ractopamine program means without a common superscript letter differ (P < 0.05).
[c] Control: no RAC; Step-up: 4.5 g/ton RAC wk 0-3, 9.0 g/ton RAC wk 4-6; Constant: 9.0 g/ton RAC wk 0-6.
[d] Pooled standard error of ractopamine program means.
[e] AIAO: All-in, all-out environment; CF: Continuous flow environment.
[f] Pooled standard error of sex and environment means.
[g] % Light pigs/pen equals the mean percentage of pigs/pen that did not reach a minimum market weight (220 lb) and did not go to slaughter.
[h] Means adjusted with a common hot carcass weight; mean = 189.8 lb.
[i] RAC x SEX interaction (P < 0.01).

Table 5. The effect of ractopamine use programs on predicted body composition and tissue

	AIAO[a]			CF[a]			Std. Error[c]	Significance, P <		
	CRL[b]	STP[b]	CON[b]	CRL[b]	STP[b]	CON[b]		RAC	ENV	RAC x ENV
No. of pigs	24	24	24	24	24	24				
Tissue Mass, lb										
Day 0										
FFTOLN[d]	65.0	65.0	65.3	64.2	64.4	63.7	0.77	0.968	0.178	0.820
TOFAT[d]	28.7	28.2	28.0	30.4	29.5	29.1	0.53	0.167	0.005	0.702
Day 21										
FFTOLN	78.9	83.3	84.2	79.6	82.9	83.8	1.30	0.002	0.883	0.841
TOFAT	38.1	39.7	39.2	43.2	46.3	45.4	1.50	0.300	0.001	0.860
Day 42										
FFTOLN	93.9	100.3	99.4	94.1	99.9	100.3	1.57	0.001	0.895	0.923
TOFAT	69.0	73.0	69.4	69.0	71.4	69.0	1.79	0.162	0.634	0.925
Rate of Gain, lb/d[f]										
Day 0-21										
FFTOLN	0.665	0.877	0.907	0.733	0.883	0.952	0.052	0.001	0.354	0.834
TOFAT	0.456	0.544	0.535	0.604	0.817	0.782	0.066	0.061	0.001	0.603
Day 21-42										
FFTOLN	0.716	0.793	0.725	0.714	0.841	0.775	0.049	0.125	0.428	0.827
TOFAT	1.463	1.566	1.436	1.240	1.178	1.139	0.073	0.506	0.001	0.551
Day 0-42										
FFTOLN	0.689	0.846	0.815	0.707	0.846	0.870	0.035	0.001	0.427	0.738
TOFAT	0.960	1.057	0.987	0.910	0.998	0.949	0.038	0.064	0.128	0.964

[a] AIAO: All-in, all-out environment; CF: Continuous flow environment.
[b] CRL: Control, no RAC; STP: Step-up, 4.5 g/ton RAC wk 0-3, 9.0 g/ton RAC wk 4-6; CON: Constant, 9.0 g/ton RAC wk 0-6.
[c] Pooled standard error of RAC x ENV means.
[d] FFTOLN: Fat-free total lean; TOFAT: Total carcass fat.
[f] Tissue accretion rates were calculated by subtracting initial predicted composition from final predicted composition and dividing by the number of days in the given period.

Table 6. Percentage of ractopamine fed pigs with positive levels of plasma antibodies to three porcine respiratory diseases and reared in two different environmental health conditions

	AIAO[a]			CF[a]		
	Control[b]	**Step-up[b]**	**Constant[b]**	**Control[b]**	**Step-up[b]**	**Constant[b]**
M. hyo [c,d]						
day 0	6.25	6.25	6.25	75.00	75.00	100
day 14	6.25	12.50	18.75	68.75	93.75	87.50
day 28	12.50	12.50	12.50	93.75	93.75	100
day 42	6.25	12.50	12.50	87.50	93.75	100
PRRS [c,d]						
day 0	0	0	0	100	100	100
day 14	0	6.25	0	100	93.75	93.75
day 28	0	6.25	0	93.75	87.50	93.75
day 42	0	6.25	0	100	87.50	87.50
SIV [c,d]						
day 0	37.50	37.50	37.50	41.67	50.00	41.67
day 14	62.50	56.25	31.25	37.50	43.75	68.75
day 28	37.50	37.50	37.50	62.50	37.50	43.75
day 42	50.00	62.50	75.00	100	93.75	100
% Treated [e, f]	6.25	3.13	6.25	38.71	38.71	58.06

[a] AIAO: All-in, all-out environment; CF: Continuous flow environment.
[b] Control: no RAC; Step-up: 4.5 g/ton RAC wk 0-3, 9.0 g/ton RAC wk 4-6; Constant: 9.0 g/ton RAC wk 0-6.
[c] *M. Hyo*: *Mycoplasma hyopneumoniae*; PRRS: porcine reproductive and respiratory syndrome virus; SIV: swine influenza virus.
[d] Environment effect (P < 0.001); Ractopamine effect (P > 0.20).
[e] Percent of pigs that required therapeutic treatment with injectable antibiotics at least once throughout the study.
[f] Environment effect (P < 0.001); Ractopamine effect (P > 0.72).

Table 7. Plasma hormone concentrations in ractopamine fed pigs reared in two different environmental health conditions

	AIAO[a]			CF[a]			Std. Error	Significance, P <		
	Control[b]	Step-up[b]	Constant[b]	Control[b]	Step-up[b]	Constant[b]		RAC	ENV	RAC x ENV
GH, ng/mL								0.512	0.118	0.508
day 0	9.31	9.31	9.31	11.75	11.28	7.88	1.73			
day 14	10.11	8.31	11.01	11.19	11.93	12.08	0.87			
day 28	10.77	9.35	9.82	9.24	9.14	9.61	0.87			
day 42	8.82	7.90	8.50	9.32	8.60	7.84	0.87			
IGF-I, ng/mL								0.483	0.031	0.008
day 0	100.97	100.97	100.97	91.30	131.09	107.13	16.7			
day 14	101.44	97.15	110.04	112.18	127.25	89.68	7.96			
day 28	152.09	149.51	139.63	124.25	129.10	105.61	7.90			
day 42	141.37	121.47	136.90	132.62	130.22	109.63	7.93			

[a] AIAO: All-in, all-out environment; CF: Continuous flow environment.
[b] CRL: Control, no RAC; STP: Step-up, 4.5 g/ton RAC wk 0-3, 9.0 g/ton RAC wk 4-6;
CON: Constant, 9.0 g/ton RAC wk 0-6.