Evaluation of different doses and durations of ractopamine (Paylean) on growth performance and carcass characteristics of late finishing market pigs

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ABSTRACT

The objective was to evaluate varying doses and durations of ractopamine hydrochloride (RAC; Paylean, Elanco Animal Health, Greenfield, IN) on growth performance and carcass characteristics. Finishing pigs were allotted to 12 treatments 35 d before market. Treatments consisted of negative control [NEG; 13.13% CP, 0.64% standard ileal digestible (SID) Lys] and positive control (POS; 17.77% CP, 0.94% SID Lys); and 2 RAC diets (5 or 7.4 mg/kg) that were fed for the last 7, 14, 21, 28, or 35 d before market. No differences (P > 0.05) were observed between 5 and 7.4 mg/kg of RAC; therefore, the 2 doses were pooled and compared with the NEG and POS diets. Feeding RAC (pooled average for the RAC groups) increased (P = 0.004) final BW by ~3 kg, overall ADG by 12% (P < 0.001), and overall G:F by 14%, but did not affect (P = 0.589) overall ADFI compared with the NEG control. Ractopamine increased (P < 0.05) carcass weight by ~2 kg, loin depth by 0.24 cm, and estimated percent lean by 0.64 units, while reducing BF depth by 1.22 mm compared with the NEG diet. Carcass weight, carcass yield, and loin depth increased linearly (P < 0.05) as RAC feeding duration increased, whereas BF depth and estimated carcass lean increased in a quadratic manner (P < 0.05) as RAC feeding duration increased. These data demonstrate that feeding RAC improves growth performance and carcass characteristics compared with the NEG diet. Additionally, the 35-d RAC data illustrate that growth responses observed with RAC feeding programs are not due solely to increased SID Lys levels.

Key words: dose, duration, Paylean, pig, ractopamine hydrochloride

INTRODUCTION

Ractopamine hydrochloride (RAC; Paylean, Elanco Animal Health, Greenfield, IN) is approved for finishing swine in the United States for increased rate of gain, improved feed efficiency, and increased carcass leanness for the last 20 to 41 kg of BW gain (FDA, 2006). Because it is widely accepted that pigs fed RAC require a diet higher in total Lys than control-fed pigs (Adeola et al., 1990; Schinckel et al., 2003); the US label requires RAC to be added to a complete diet that contains at least 16% CP.

It is well documented that RAC improves feed efficiency (Kutzler et al., 2010; Hinson et al., 2011), estimated carcass leanness (Boler et al., 2011), and carcass cutability (Crome et al., 1996; Kutzler et al., 2011) in finishing pigs. Recently, Apple et al. (2007) conducted a meta-analysis to
summarize the available published literature on the effects of feeding RAC at doses of 5, 10, and 20 mg/kg on growth and carcass traits in finishing pigs. However, the majority of the studies summarized in the meta-analysis compared 1) RAC doses over one duration; 2) RAC to control diets with the same CP and Lys; 3) RAC doses in university settings with small pen sizes. The current gaps in the literature for RAC in swine are information comparing 1) RAC to pigs fed a standard late finishing diet that contains lower CP and Lys; 2) the effects of RAC feeding duration on growth and carcass traits for the 2 most commonly used doses (5 and 7.4 mg/kg) under US commercial conditions; 3) RAC feeding programs under US commercial conditions. Therefore, the objectives of this experiment were to evaluate the effects of different doses and durations of RAC feeding programs on growth performance and carcass characteristics when treatment groups were fed different diets that were formulated to mimic current industry practices for each treatment group.

**MATERIALS AND METHODS**

Experimental procedures during the experiment followed the guidelines stated in the Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching (FASS, 1999).

**Animals and Housing**

The pigs used in this trial represent the entire population of pigs from the carcass cutability data reported by Kutzler et al. (2011). A total of 1,708 late finishing pigs (92.68 kg initial BW; TR4 × PIC C22) were used in the experiment. The experiment was conducted as a randomized complete block design in a commercial research facility with 2 control diets: negative control (NEG; 13.13% CP, 0.64% standard ileal digestible (SID) Lys) and positive control (POS; 17.77% CP, 0.94% SID Lys); and 2 RAC diets (5.0 or 7.4 mg/kg; 17.77% CP, 0.94 SID Lys) fed for 7, 14, 21, 28, or 35 d before market for a total of 12 treatments. There were 8 replicates of each control treatment and 7 replicates of each RAC treatment for a total of 86 single-sex test pens with 18 to 21 pigs per pen (average space of 0.75 m²/pig). Pigs were housed in a curtain-sided, naturally ventilated barn. Each pen had a single cup waterer and a 4-hole single-sided box feeder that provided approximately 122 cm of linear feed space. Pigs were allotted to pens when the population BW was approximately 25 kg. During allotment, pigs were sexed, visually sized, and placed in single-sex pens with equal body size. Pen weights and feed disappearance were recorded weekly for the duration of the 35-d experiment. All pens were marketed at d 35 to a commercial Midwest slaughter facility to obtain carcass measurements. Pigs were marketed on 2 different days, and slaughter day was considered the blocking criteria. Blocks consisted of single-sex replicates that had 12 pens each (1 pen per treatment group). The first slaughter day (block 1) included 2 barrow replicates and 1 gilt replicate. The second slaughter day (block 2) included 2 gilt replicates, 1 barrow replicate, and 1 each of an incomplete barrow and gilt replicate.

**Diets**

Diets consisted of 2 control diets: negative control [NEG; 13.13% CP, 0.64% standard ileal digestible (SID) Lys] and positive control (POS; 17.77% CP, 0.94% SID Lys); and 2 RAC diets (5.0 or 7.4 mg/kg; 17.77% CP, 0.94 SID Lys) fed for 7, 14, 21, 28, or 35 d before market (Table 1). Standardized AA ratios were maintained at levels that were deemed appropriate to maximize growth potential within each diet and were the same between the POS and RAC diets. Diets for the POS control and RAC-fed pigs were based on previous research conducted in the same facility on this genotype of pig (Fernández-Dueñas et al., 2008). Pigs fed the ractopamine programs were fed the NEG diet until the initiation of RAC treatment. At that time, CP was increased to the same level as the POS to comply with RAC label requirements. The 35-d duration groups received treatment feed at allotment. The 28-d duration groups began receiving treatment feed 7 d after allotment. The 21-d duration groups began receiving treatment feed 14 d after allotment and so on for the other duration treatment groups. All other nutrients within each diet met or exceeded NRC (1998) nutrient recommendations. Pigs were allowed ad libitum access to feed and water throughout the entire feeding trial.

**Slaughter Procedures and Carcass Characteristics**

At the conclusion of the feeding period, pigs were transported approximately 630 km to a federally inspected slaughter facility. Pigs were allowed an overnight fast and were slaughtered the next morning via electrical immobilization and exsanguination. Hot carcass weight was recorded just before the carcasses entering the chiller. Carcass yield was calculated by dividing the HCW by the final farm weight. Backfat depth and loin depth were measured using the Animal Ultrasound System (Animal Ultrasound Services and Co. Inc., Ithaca, NY). Estimated carcass lean was provided using a calculated plant proprietary equation.

**Statistical Analysis**

All data were analyzed with the MIXED procedure of SAS (SAS Institute Inc., Cary, NC), where pen served as the experimental unit. Treatment was the main effect, whereas block and replicate nested within block were included in the model as random effects. Sex was not included in the model because the variation due to sex was accounted for by including replicate in the model as a random variable. This experimental design used 12 treatments resulting in 11 preplanned orthogonal contrast statements, which were used to test for differences between 1) NEG vs.
was fed, not the entire 35-d treatment period. As an example, 21-d duration data are representing the performance of the NEG, POS, and 21-d RAC treatments for the final 21 d of the experiment, with d 0 to 14 data being excluded for all treatments. Data within each period were analyzed with the MIXED procedure of SAS with pen serving as the experimental unit. Treatment was the main effect, whereas block and replicate nested within block were included in the model as random effects.

### RESULTS AND DISCUSSION

There were no differences between pigs fed RAC at 5 mg/kg and pigs fed RAC at 7.4 mg/kg, so the 2 doses were pooled for comparison with the NEG and POS control groups. The NEG and POS control groups were not pooled even in cases of no differences between the control groups because a comparison between pigs fed NEG control and pigs fed RAC provides a resource for producers because typical swine finishing diets (in the absences of RAC) will be formulated with approximately 13% CP, but label requirements for RAC suggest feeding a diet containing at least 16% CP. Therefore, making comparisons between pigs fed RAC and those not fed RAC in diets differing in CP allows for comparisons in an industry-applicable scenario. On the other hand, comparing RAC-fed pigs with POS-control pigs allows for a true test of RAC response independent of CP.

### Overall Growth Performance

Initial BW between NEG (92.73 kg) and POS (92.87 kg) were not different between the control groups ($P = 0.859$) or among the controls and the RAC-fed pigs ($P > 0.691$; Table 2). By the end of the 35-d feeding trial, the POS control pigs were 2.76 kg heavier ($P = 0.004$) than the NEG control pigs. Heavier 35-d BW can be attributed to higher ($P = 0.016$) ADG and improved feed efficiency ($P < 0.001$) for the POS (0.75 kg; 0.327) when compared with the NEG controls (0.68 kg; 0.292). There were no differences ($P = 0.330$) in ADFI between the control groups (Table 2).

Pigs fed RAC, regardless of duration, were 2.86 kg heavier ($P = 0.004$) and grew 80 g/d more ($P < 0.001$) than NEG control pigs. The 2.86 kg improvement represented a 2.46% increase in BW. Hinson et al. (2011) reported a 3.37% increase in BW in pigs fed 7.4 mg/kg RAC for 21 d before slaughter when compared with pigs not fed RAC. Pigs in that experiment were fed diets differing in CP levels where RAC-fed pigs were fed approximately 18.29% and controls were fed diets that averaged 13.67%. This shows the RAC response in the current experiment was comparable and with experiments previously reported and conducted in a similar manner.

### Table 1. Dietary composition, as-fed basis

<table>
<thead>
<tr>
<th>Item</th>
<th>Negative control</th>
<th>Positive control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ingredient, %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corn</td>
<td>80.52</td>
<td>68.44</td>
</tr>
<tr>
<td>Soybean meal 48%</td>
<td>13.25</td>
<td>25.00</td>
</tr>
<tr>
<td>Fat, choice white grease</td>
<td>4.00</td>
<td>4.00</td>
</tr>
<tr>
<td>Monocalcium phosphate</td>
<td>0.65</td>
<td>0.80</td>
</tr>
<tr>
<td>Limestone</td>
<td>0.90</td>
<td>0.95</td>
</tr>
<tr>
<td>Salt</td>
<td>0.40</td>
<td>0.40</td>
</tr>
<tr>
<td>L-Lys</td>
<td>0.15</td>
<td>0.15</td>
</tr>
<tr>
<td>Alimet†</td>
<td>0.00</td>
<td>0.038</td>
</tr>
<tr>
<td>L-Thr</td>
<td>0.013</td>
<td>0.075</td>
</tr>
<tr>
<td>Vitamin premix†</td>
<td>0.025</td>
<td>0.025</td>
</tr>
<tr>
<td>Mineral premix†</td>
<td>0.04</td>
<td>0.04</td>
</tr>
<tr>
<td>Copper sulfate</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>Calculated analysis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NRC ME, kcal/kg</td>
<td>3.523</td>
<td>3.510</td>
</tr>
<tr>
<td>CP, %</td>
<td>13.13</td>
<td>17.77</td>
</tr>
<tr>
<td>Lys, %</td>
<td>0.73</td>
<td>1.05</td>
</tr>
<tr>
<td>TID Lys, %</td>
<td>0.64</td>
<td>0.94</td>
</tr>
<tr>
<td>Available P, %</td>
<td>0.19</td>
<td>0.24</td>
</tr>
<tr>
<td>Calcium, %</td>
<td>0.50</td>
<td>0.58</td>
</tr>
</tbody>
</table>

†Ractopamine hydrochloride [Paylean 9; Paylean is a registered trademark of Eli Lilly and Company (Elanco Animal Health), Greenfield, IN] was included in the positive control diet in place of corn to provide the additional experimental diets. Paylean was included in the diet to provide 5 or 7.4 mg/kg ractopamine.

‡-Met precursor HMTBA, an 88% aqueous solution of 2-hydrox-4-(methylthio)butanic acid, Novus International Inc., St. Louis, MO.

§Provided per kilogram of final diet: vitamin A, 5,512 IU; vitamin D₃, 827 IU; vitamin E, 22 IU; vitamin K, 2.2 IU; riboflavin, 4 mg; vitamin B₁₂, 0.02 mg; d-pantothenic acid, 14 mg; niacin, 25 mg; iron, 146 mg; zinc, 146 mg; manganese, 34 mg; copper, 15 mg; iodine, 0.3 mg; selenium, 0.3 mg.
There were no differences ($P = 0.589$) in ADFI between RAC-fed pigs and NEG controls (Table 2). This resulted in a 14% improvement ($P < 0.001$) in G:F of the RAC-fed pigs compared with the NEG controls. Even though there was not a difference ($P = 0.459$) in 35-d BW between the pigs fed the POS control diet and pigs fed RAC for 35 d, the 35 d RAC-fed pigs had higher ($P = 0.077$) ADG and improved G:F ratios ($P = 0.002$). Feeding a RAC program for up to 35 d did not affect ADFI ($P = 0.446$) compared with the POS control group (Table 2). Armstrong et al. (2004) reported improvements in G:F of RAC-fed pigs compared with controls fed a diet containing 18.5% CP (similar to the POS control in the current experiment) when RAC was fed for as little as 6 d at doses as low as 5 mg/kg. Most historical data report an increase in feed efficiency regardless of dose or duration (Patience et al., 2009, 5.0 mg/kg 28 d; Hinson et al., 2011, 7.4 mg/kg for 21 d; Kutzler et al., 2010, 10.0 mg/kg for 28 d; See et al., 2004, 11.7 mg/kg for 41 d).

### Weekly Growth Performance

As mentioned above, feeding the POS diet increased overall ADG by 10% ($P = 0.016$) and overall G:F by 12% ($P < 0.001$) when compared with the NEG diet. This somewhat confounds the contrast of POS vs. RAC for these parameters because RAC treatments with feeding durations of 7, 14, 21, and 28 were fed the NEG diet for 28, 21, 14, and 7 d before the initiation of RAC. Therefore, growth performance traits between NEG, POS, and RAC were compared for only the time period in which RAC was fed (Table 3). Advantages in G:F were detected in RAC-fed pigs compared with NEG controls as early as 7 d on RAC and as early as 14 d compared with POS controls. Ractopamine-fed pigs had higher ($P < 0.05$) G:F ratios compared with either NEG or POS controls when RAC was fed for 14, 21, 28, or 35 d. 

End of trial BW were heavier and ADG were higher for RAC-fed pigs
Ractopamine feeding dose and duration

...when compared with NEG controls when RAC was fed for as little as 14 d. End of trial BW were not different between POS controls and RAC-fed pigs regardless of RAC feeding duration. Even so, RAC-fed pigs had greater ADG when compared with POS-control-fed pigs when RAC was fed for 14, 21, and 28 d. There were no differences (P > 0.05) for ADFI among any treatment group regardless of RAC duration.

It is known that low RAC doses (5 mg/kg) will influence growth performance (Armstrong et al., 2004), but higher doses for longer durations are required to influence carcass characteristics and carcass cutability (Kutzler et al., 2011). Even so, Armstrong et al. (2004) reported that pigs fed 5 mg/kg RAC for 27 d were still 4.3 kg heavier (P < 0.05) than their high-protein-fed control counterparts, and when pigs were fed 5 mg/kg RAC for 34 d, the magnitude of difference between the treatments increased to 8.1 kg (P < 0.05). In the current experiment, the difference in BW at 28 d on test was only 0.87 kg and when on test for 35 d was 1.26 kg (Table 3). Control pigs in the study of Armstrong et al. were 0.4 kg lighter than RAC-fed pigs at the time of RAC initiation. In the current experiment, RAC-fed pigs were 0.66 kg lighter at the time of RAC...
initiation than the POS-control-fed pigs. Therefore, RAC-fed pigs gained 1.53 kg more (20.82 vs. 22.35 kg) during the time on RAC. This may partially explain the lack of statistical response to RAC in ending BW when compared with the POS controls. An additional explanation for the lack of a greater response in ADG with the feeding of RAC could be related to the relatively low ADFI that were observed in this trial. Typical ADFI within this facility, during the time of the year this trial was conducted, and with the same genetics would range from 2.6 to 3.0 kg/d (R. B. Hinson, unpublished data). Average daily ambient temperature during the duration of this trial was 23.6°C, with average daily ambient high temperature averaging 29.5°C. With reduced ADFI, pigs consuming the POS diets would have a higher daily intake of ME and amino acids than the NEG control treatments due to the increased nutrient density of the POS control diets. More important, however, pigs fed RAC for as little as 14 d were 3.46 kg heavier (P < 0.05) than the NEG controls. This potentially allows the RAC-fed pigs to reach a desired market weight at fewer days on feed when compared with the industry applicable (NEG) control.

**Carcass Characteristics**

Though statistically similar (P = 0.104), carcass weights of POS-control-fed pigs were 1.65 kg heavier than carcass weights of NEG-control-fed pigs (Table 4). Carcass yield was not different (P = 0.316) between NEG (75.16%) and POS (74.78%). There were only subtle differences in carcass measurements between the control groups for backfat depth (P = 0.120) and loin depth (P = 0.069), but these translated into a 0.6 percentage unit improvement (P = 0.034) in estimated carcass lean of the POS control (55.56%) compared with the NEG control (54.96%). In the current experiment, the POS control diet had 0.30 percentage units more SID Lys than the NEG control diet. Even so, Frantz et al. (2009) did not report a linear response to increasing SID Lys from 0.66% SID Lys to 1.05% SID Lys in pigs fed 5 mg/kg RAC for either HCW (linear P = 0.99) or lean percentage (linear P = 0.58). Therefore, differences found in BW between RAC-fed pigs and control pigs must be at least partially due to RAC.

Pigs fed RAC had 2.41 kg heavier carcasses (P = 0.002), 1.05 mm less backfat (P = 0.051), 0.24 cm larger loin depths (P = 0.004), and 0.64 percentage units improvement (P = 0.003) in estimated carcass lean compared with NEG controls (Table 4). Historically, RAC will increase HCW by an average of 2.3% when fed at 5.0 mg/kg and 3.2% when fed at 10 mg/kg (Apple et al., 2007). So the 2.75% improvement in carcass weight of the RAC-fed pigs compared with the NEG controls in the current experiment was to be expected. There was no difference (P = 0.530) in carcass yield between the NEG- and RAC-fed pigs, but RAC-fed pigs had a carcass yield that was 0.56 percentage units higher (P = 0.051) than POS controls. Negative control pigs were 1.05 mm fatter (18.62 vs. 17.57 mm) than RAC-fed pigs. Positive control pigs were 0.06 mm leaner than RAC-fed pigs. It has been historically accepted that fatter pigs usually have higher carcass yields than lean pigs (Zobrisky et al., 1959) and RAC is known to improve carcass yield (Apple et al., 2007). Therefore, the difference in carcass yield between the RAC-fed pigs and POS pigs as well as the lack of difference in carcass yield between RAC-fed pigs and NEG pigs was expected. Another possible explanation for the difference in carcass yields between the POS control and RAC-fed pigs is the inclusion level of soybean meal (SBM) in the diets. Both the POS diets and the RAC diets contain 25% SBM. The NEG control diet only has 13.25% SBM. Gaines et al. (2007) indicated higher levels of dietary SBM may decrease carcass yield. If this is the case, the higher inclusion of SBM in the POS (and RAC) diets may reduce carcass yield compared with the NEG diet. Therefore, the inclusion of RAC (which is known to improve carcass yield) in the POS diet may have offset the difference in carcass yield and lead to no differences compared with the NEG control (which had less SBM). Additionally then, the increased carcass yield of the RAC-fed pigs compared with the POS control (same levels of dietary SBM) would also be expected. Even so, the difference falls within the expected range of 0.2 and 0.6 percentage unit improvement suggested by Apple et al. (2007). The improvement in carcass characteristics in RAC-fed pigs compared with the NEG controls coupled with the lack of differences in some carcass characteristics between the NEG and POS controls further demonstrates the efficacy of RAC over just increasing dietary CP. Furthermore, Webster et al. (2007) did not report an increase (linear P = 0.37) in BW as total dietary Lys level was increased from 0.6% to 1.2%. Additionally, increasing dietary Lys in control-fed pigs (no dietary RAC) did not influence HCW (linear P = 0.29), carcass yield (linear P = 0.63), 10th-rib fat thickness (linear P = 0.92), loin eye area (linear P = 0.75), or calculated carcass lean (linear P = 0.89).

Increasing the duration of a RAC feeding program linearly increased carcass weight (P = 0.002), carcass yield (P = 0.034), loin depth (P = 0.002), and estimated carcass lean (P < 0.001). It also resulted in a linear (P = 0.004) and quadratic (P = 0.031) decrease in 10th-rib fat depth (Table 4). As already stated, detectable differences in carcass characteristics between RAC-fed pigs and controls historically require higher doses or longer durations to be realized than growth parameter responses. Though not tested with polynomial contrast statements, Armstrong et al. (2004) reported increasing BW and HCW in pigs fed 10 mg/kg RAC as duration increased from 6 d on test up to 27 d.

**IMPLICATIONS**

These data indicate feeding RAC and feeding RAC for longer dura-
Ractopamine feeding dose and duration

**Table 4. Effects of ractopamine (RAC) feeding dose on carcass characteristics**

<table>
<thead>
<tr>
<th>Item</th>
<th>Control</th>
<th>NEG vs. POS</th>
<th>NEG vs. RAC</th>
<th>POS vs. RAC</th>
<th>POS vs. 35-d RAC</th>
<th>RAC linear</th>
<th>RAC quadratic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carcass wt, kg</td>
<td>87.58</td>
<td>88.18</td>
<td>88.18</td>
<td>88.18</td>
<td>90.58</td>
<td>0.002</td>
<td>0.002</td>
</tr>
<tr>
<td>Carcass yield, %</td>
<td>75.16</td>
<td>75.00</td>
<td>75.00</td>
<td>75.00</td>
<td>75.16</td>
<td>0.034</td>
<td>0.034</td>
</tr>
<tr>
<td>Backfat depth, mm</td>
<td>18.62</td>
<td>18.90</td>
<td>18.90</td>
<td>18.90</td>
<td>17.51</td>
<td>0.004</td>
<td>0.004</td>
</tr>
<tr>
<td>Loin depth, cm</td>
<td>6.77</td>
<td>6.84</td>
<td>6.84</td>
<td>6.84</td>
<td>7.08</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Estimated carcass lean, %</td>
<td>54.96</td>
<td>55.00</td>
<td>55.00</td>
<td>55.00</td>
<td>55.78</td>
<td>0.034</td>
<td>0.034</td>
</tr>
</tbody>
</table>

- NEG = negative control, 13% CP.
- POS = positive control, 17.8% CP.
- Pooled RAC (Elanco Animal Health, Greenfield, IN) 5.0 and 7.4 mg/kg dose.
- POS vs. NEG contrast P-value of POS control vs. NEG control.
- RAC vs. POS contrast P-value of RAC control vs. POS control.
- NEG vs. RAC contrast P-value of NEG control vs. RAC response averaged across durations.
- POS vs. 35-d RAC contrast P-value of POS control vs. 35-d RAC response.
- RAC linear contrast P-value of linear RAC duration response.
- RAC quadratic contrast P-value of quadratic RAC duration response.

**LITERATURE CITED**


