Effects of ractopamine hydrochloride on the growth performance and carcass characteristics of heavy-weight finishing pigs sent for slaughter using a 3-phase marketing strategy

J. W. Rickard,* G. L. Allee,† P. J. Rincker,‡ J. P. Gooding,‡ R. J. Acheson,§ D. R. McKenna,§ C. L. Puls,‡ and S. N. Carr‡

*Department of Agriculture, Illinois State University, Normal 61790; †Porktech, LLC, Columbia, MO 65203; ‡Elanco Animal Health, Greenfield, IN 46140; and §Tyson Foods, Dakota Dunes, SD 57049

ABSTRACT: A total of 2,158 crossbred pigs was used to evaluate the effects of feeding 7.4 mg/kg ractopamine hydrochloride (RAC) on the growth performance and carcass characteristics of heavy-weight finishing pigs sent to slaughter using a 3-phase marketing strategy. The study was performed from 121.0 ± 4.28 kg to 144.5 ± 4.73 BW using a randomized complete block design (blocking factor was d of start on test) with 2 treatments (0 vs. 7.4 mg/kg RAC). Pigs were housed in a commercial wean-to-finish facility in groups of approximately 25 (44 groups/treatment), with ad libitum access to feed and water throughout the study, and pen weights of pigs were recorded at the start (d 0), and on d 7, 21, and 35 of study. Pigs were sent for slaughter according to the following marketing strategy: 1) after 7 d on RAC, the heaviest 16% of each pen was sent for slaughter (Phase 1), 2) after 21 d on RAC, the next 40% of each pen was sent for slaughter (Phase 2), and 3) after 35 d on RAC, the remaining 44% of each pen was sent for slaughter (Phase 3). Pigs were selected for slaughter by visual appraisal and shipped to a commercial facility where standard carcass measurements (HCW, LM depth, and backfat depth) were measured. Overall, feeding RAC increased (P < 0.001) ADG (18.8%) and G:F (23.7%) compared to the control, but lowered (P < 0.001) ADFI (3.3%). In addition, feeding RAC increased (P < 0.001) HCW (3.9 kg), carcass yield (0.7% units), LM depth (5.0%), and predicted lean content (1.0% units), and reduced backfat depth (6.3% lower) compared to controls. With each subsequent phase of marketing, the magnitude of improvements in response to feeding RAC decreased for ADG (43.1, 20.9, and –3.1% for Phase 1, 2, and 3, respectively) and G:F (37.5, 25.8, and 6.4% for Phase 1, 2, and 3, respectively); however, improvements in HCW (1.6, 4.5, and 4.2 kg for Phase 1, 2, and 3, respectively), carcass yield (0.2, 0.6, and 0.9% units for Phase 1, 2, and 3, respectively), LM depth (2.3, 5.7, and 5.2% for Phase 1, 2, and 3, respectively), and predicted lean content (0.2, 1.0, and 1.3% units for Phase 1, 2, and 3, respectively) generally increased from feeding RAC. These results suggest that while improvements in growth performance from feeding RAC will generally decline after 21 d of feeding, improvements in carcass traits, particularly carcass yield and lean content, will continue with feeding RAC until d 35.

Key words: carcass, growth, marketing, Paylean, pigs, ractopamine

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INTRODUCTION

Ractopamine hydrochloride (RAC; Paylean, Elanco Animal Health, Greenfield, IN) is a β-agonist used during the marketing period in late-finishing pigs to improve growth performance and carcass leanness (Apple et al., 2007). Most studies evaluating RAC have been performed in academic settings with relatively limited group sizes and numbers of pigs and ends after a fixed-time feeding duration (Armstrong et al., 2004; Puls et al., 2015). However, in a commercial setting, pigs are often sent for slaughter using a multiple-phase
marketing strategy to minimize variation in HCW and lean percentage, resulting in variable days on RAC. This marketing strategy has been shown to increase the growth performance (ADG, ADFI, and G:F) of pigs remaining in the pen after the heaviest pigs are sent for slaughter (DeDecker et al., 2005; 2007; Gerlemann et al., 2013). In theory, the increase in ADFI may result in greater RAC intake and could lead to a greater response to RAC in pigs sent later in the marketing period. Conversely, it has been shown that the improvements in growth performance generally decline as RAC feeding duration increases (Dunshea et al., 1993; Williams et al., 1994; Christianson et al., 2014), but previous research has also reported that carcass improvements continue with increasing time on RAC (Armstrong et al., 2004; Christianson et al., 2014; Gerlemann et al., 2014). Slaughter weights of pigs continue to increase, reaching near record highs for the US in 2013 through 2014, and there is a need to determine the effects of RAC in heavy-weight pigs (> 136 kg BW) managed in a commercial setting. This is the first study, to the authors’ knowledge, to evaluate effects of feeding RAC in this heavy weight of pig. Therefore, the objective of this study was to evaluate the effects of feeding 7.4 mg/kg RAC on the growth performance and carcass characteristics of heavy-weight finishing pigs sent for slaughter using a 3-phase marketing strategy.

**MATERIALS AND METHODS**

All experimental procedures and animal care were approved by the Elanco Animal Health Institutional Animal Care and Use Committee (EIAC-0141).

**Experimental Design and Treatments**

The study was performed for 35 d from 121.0 ± 4.28 kg to 144.5 ± 4.73 kg BW using a randomized complete block design (blocking factor was d of start on test) with 2 treatments (0 vs. 7.4 mg/kg RAC). A total of 2,158 crossbred barrows and gilts were housed in 88 pens (44 single-sex replicates/treatment group). Ractopamine was added to the diets beginning on d 0 and remained at a constant level throughout the study period.

Pen was the experimental unit for all measurements.

**Animals and Allotment to Study**

Pigs used in the study were the progeny of PIC 337 sires × C22 dams (PIC North America, Hendersonville, TN). A total of 88 single-sex pens, each initially housing 25 pigs, were stratified over 2 blocks that were used in the experiment.

Allotment to the study was performed within sex at approximately 152 d of age. Within sex, pigs were weighed as a group (pen weight) and formed into outcome groups of 2 pens of similar BW, and were randomly allotted from within outcome group to treatment. Following allotment, pigs were moved to their allotted location within the facility and allowed a 15 d acclimation period prior to start of the RAC feeding period.

**Animal Housing and Management**

Prior to the start of the growth study, pigs were managed according to standard unit protocols, with ad libitum access to standard diets that were formulated to meet or exceed the nutrient requirements of growing pigs recommended by NRC (2012). During the study period, pigs were housed in a curtain-sided, naturally ventilated facility that had fully-slotted concrete floors. Pen dimensions provided a usable floor space of 16.25 m², which resulted in 0.65 m²/pig prior to the first group of pigs being sent for slaughter. Each pen had a 4-space single-sided dry box feeder mounted on the pen division that provided a total of 122 cm of linear feeder space (4.88 cm/pig) and a single cup water drinker.

**Diets and Feeding**

Two diets were used during the study period: 1) Control diet (0 mg/kg RAC) vs. 2) RAC diet which included 7.4 mg/kg RAC and increased lysine for the 35 d RAC feeding period (Table 1). Diets were formulated to meet or exceed the nutrient requirements of finishing pigs recommended by NRC (2012). Diet formulations and calculated composition of the diets fed during the experimental period are presented in Table 1.

Pigs had ad libitum access to feed and water throughout the study period.

**Marketing Strategy**

Pigs were sent for slaughter according to the following marketing strategy: 1) after 7 d on test, the heaviest 16% of each pen (i.e., 4 pigs) was sent for slaughter such that 21 pigs remained in the pen (Phase 1); 1) after 21 d on RAC, the next heaviest 40% of each pen (i.e., 10 pigs) was sent for slaughter such that 11 pigs remained in the pen (Phase 2); and 3) after 35 d on RAC, the remaining 44% of each pen (i.e., 11 pigs) was sent for slaughter (Phase 3; Table 2). Adjustments were made to the number of pigs removed to account for differences in morbidity and mortality. Pigs were selected for slaughter by visual appraisal by the production site’s normal marketing personnel. At the end of each marketing phase (d 7, 21, and 35), pigs were weighed as a group, and the heaviest pigs were selected for slaughter and re-

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moved from the group, which was weighed again to achieve a start weight for the subsequent marketing phase. The pigs selected for slaughter were weighed as a group, tattooed, loaded on a conventional semi-trailer, and shipped approximately 725 km (4.5 h) to a commercial slaughter facility. Descriptions of housing and marketing conditions are presented in Table 2.

### Growth Study Measurements

All pigs were weighed as a group (i.e., pen basis) on d 0 (start of the RAC feeding period), and on d 7, 21, and 35 (end) of the study period. All feed additions to the feeders were recorded and feed disappearance was recorded at the time of pig BW collection and used to calculate ADFI and G:F.

### Carcass Measurements

Pigs were unloaded and held in lairage overnight with access to water, but not feed, and were humanely slaughtered using standard procedures. Immediately after carcass dressing, HCW was recorded, and backfat and LM depth were measured using the Animal Ultrasound Services Carcass Value Technology System (Animal Ultrasound Services Inc., Ithaca, NY). Predicted lean content was calculated using a plant-proprietary equation using these measurements.

### Statistical Analysis

All variables were analyzed using PROC MIXED of SAS (SAS Inst. Inc., Cary, NC). The pen of pigs was the experimental unit for all measurements. The model included the fixed effects of RAC treatment and random effects of block and replicate nested within block. Sex was not included in the statistical model, but was accounted for as replicate (single-sex) was included in the random statement. Least-squares means were separated using the PDIFF option of SAS with means being considered different at a $P \leq 0.05$.

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

| Item                                      | Ractopamine inclusion level, mg/kg |
|-------------------------------------------|-------------------------------------|
| Ingredient, %                             |                                     |
| Corn                                      | 82.94 73.32                         |
| Soybean meal 48%                         | 13.00 22.25                         |
| Choice white grease                      | 2.00 2.00                           |
| Monocalcium                               | 0.50 0.65                           |
| Limestone                                 | 0.85 0.80                           |
| Salt                                      | 0.40 0.40                           |
| L-Lysine                                  | 0.17 0.25                           |
| L-Threonine                               | 0.01 0.12                           |
| Alimet¹                                   | - 0.05                              |
| Vitamin premix with phytase²             | 0.03 0.03                           |
| Mineral premix³                          | 0.10 0.10                           |
| Ractopamine hydrochloride⁴               | - 0.04                              |
| Total                                     | 100 100                              |

Calculated analysis

|                         | Ractopamine inclusion level, mg/kg |
|-------------------------|-------------------------------------|
| ME, Mcal/kg             | 3.44 3.43                           |
| CP, %                   | 13.22 16.98                         |
| Total Lys, %            | 0.74 1.06                           |
| SID⁵ Lys, %             | 0.65 0.95                           |
| Total P, %              | 0.43 0.50                           |
| Available P, %          | 0.16 0.20                           |
| Ca, %                   | 0.46 0.50                           |
| g SID lysine / Mcal ME  | 1.89 2.77                           |
| SID Met:Lys             | 31.64 30.47                         |
| SID Met+Cys:Lys         | 65.37 58.20                         |
| SID Thr:Lys             | 64.27 68.20                         |
| SID Trp:Lys             | 18.09 17.58                         |
| SID Ile:Lys             | 69.37 63.79                         |
| SID Val:Lys             | 83.05 72.92                         |

¹L-Met precursor HMTBA, an 88% aqueous solution of 2-hydrox-4-(methylthio) botanic acid (Novus International Inc., St. Louis, MO).

²Provided per kg of final diet: vitamin A, 6,600 IU; vitamin D₃, 704 IU; vitamin E, 26 IU; riboflavin, 4.9 mg; menadione, 2.6 mg; vitamin B₁₂, 0.02 mg; D-pantothenic acid, 16.5 mg; and niacin, 29.7 mg.

³Provided per kg of final diet: 66 mg iron, 66 mg zinc, 19.8 mg manganese, 66 mg copper, 14 mg iodine, and 0.12 mg selenium.

⁴Provided either 0 or 7.4 mg of ractopamine hydrochloride (Paylean; Elanco Animal Health, Greenfield, IN) per kg of diet.

⁵SID = Standardized ileal digestible.

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**Table 2.** Summary of housing conditions and marketing strategy of pigs fed ractopamine hydrochloride (RAC)¹ and sent for slaughter in a 3-phase marketing strategy

| Item                                      | Housing conditions |
|-------------------------------------------|--------------------|
| Phase 1 (d 0 to 7)                         |                     |
| No. pigs/pen on d 0                      | 25                 |
| Days on RAC                              | 7                  |
| Feeder space, cm/pig                     | 4.88               |
| Floor space, m²/pig                      | 0.65               |
| Approximate % of pigs sent for slaughter/pen | 16                |
| No. pigs remaining/pen on d 7            | 21                 |
| Phase 2 (d 7 to 21)                       |                     |
| No. pigs/pen on d 7                      | 21                 |
| Days on RAC                              | 14                 |
| Feeder space, cm/pig                     | 5.81               |
| Floor space, m²/pig                      | 0.77               |
| Approximate % of pigs sent for slaughter/pen | 40               |
| No. pigs remaining/pen on d 21           | 11                 |
| Phase 3 (d 21 to 35)                      |                     |
| No. pigs/pen on d 21                     | 11                 |
| Days on RAC                              | 14                 |
| Feeder space, cm/pig                     | 11.09              |
| Floor space, m²/pig                      | 1.48               |
| Approximate % of pigs sent for slaughter/pen | 44               |

¹Trade name: Paylean, Elanco Animal Health, Greenfield, IN.
RESULTS AND DISCUSSION

The analyzed RAC level of the diet was 7.5 mg/kg which was similar to the formulated level of 7.4 mg/kg.

**Growth Performance**

Pigs fed RAC were heavier (P = 0.001) at the end of each marketing phase and for overall end weight (P = 0.001) compared to controls (Table 3). For the overall 35 d feeding period, feeding RAC increased (P = 0.001) ADG (18.8%) and G:F (23.7%), and lowered (P = 0.001) ADFI (3.3% lower) compared to controls (Table 3). Generally speaking, the improvements in growth performance from feeding 7.4 mg/kg RAC observed in the current study are slightly greater than those observed in previous research. Christianson et al. (2014) reported a 20% improvement compared to controls in overall growth rate and feed efficiency in pigs fed 7.4 mg/kg RAC for 35 d; however, Gerlemann et al. (2014) reported smaller improvements of only 10.9% and 12.9% in ADG and G:F in RAC-fed pigs, respectively, compared to controls. Christianson et al. (2014) reported no difference in overall ADFI between RAC-fed pigs and controls whereas Gerlemann et al. (2014) reported 2.7% lower ADFI for RAC-fed pigs, results similar to the current study (3.3% lower; P < 0.001; Table 3).

During Phase 1 (d 0 to d 7), feeding RAC increased (P = 0.001) ADG and G:F, but had no effect (P = 0.78) on ADFI compared to the control. During Phase 2 (d 7 to d 21), pigs fed RAC had greater (P = 0.001) ADG and G:F, and lower (P = 0.001) ADFI compared to the control. Finally, during Phase 3 (d 21 to d 35), feeding RAC had no effect (P > 0.05) on ADG, but lowered (P = 0.001) ADFI, which resulted in increased (P < 0.05) G:F compared to the control (Table 3).

Improvements over controls from feeding RAC with respect to ADG were greatest in Phase 1 (d 0 to d 7) and gradually declined with increasing time on RAC (43.1% greater, 20.9% greater, and 3.1% lower for Phases 1, 2, and 3, respectively). Interestingly, feeding RAC longer than 21 d (through Phase 3) resulted in similar (P = 0.19) ADG as the control (Table 3). Compared to the controls, feeding RAC lowered ADFI, and this reduction increased with increasing time on RAC (0.3% lower, 2.9% lower, and 6.7% lower for Phases 1, 2, and 3 respectively). Similarly, the magnitude of improvements in G:F from feeding RAC declined with increasing time on RAC (37.5, 25.8, and 6.4% greater for Phases 1, 2, and 3, respectively).

The study was designed as a fixed-time study, where pigs were removed from pens and sent for slaughter on specific d (7, 21, and 35) during the RAC feeding period. As such, the growth performance of pigs during each phase of the marketing strategy is confounded with the start and end weight of the respective phase, as RAC-fed pigs were heavier than the controls at each marketing phase. Nonetheless, feeding RAC improved the growth rate and feed efficiency of pigs compared to the controls up to the end of Phase 2, similar to the results of Armstrong et al. (2004) which demonstrated that the greatest response to RAC was measured within the first 6 d on feed, and generally speaking, the improvements in RAC declined after 20 d on feed. There is relatively limited published research utilizing a similar study duration and design in a commercial production setting as the current study. Gerlemann et al. (2014) used a similar market-
ing strategy (16, 18, and 66% of pigs sent for slaughter on d 7, 21, and 35 of RAC feeding, respectively) and reported gradual reductions in ADG (18.2, 13.0, and 1.9% for Phases 1, 2, and 3, respectively) and G:F (16.7, 21.2, and 6.9% for Phases 1, 2, and 3, respectively) as the RAC-feeding duration increased. Similarly, Christianson et al. (2014) reported continual reductions for the improvement in growth rate (30.0, 17.7, and 10.8% for Phases 1, 2, and 3, respectively) and feed efficiency (30.3, 18.9, and 8.8% for Phases 1, 2, and 3, respectively) when 26, 31, and 43% of the pen was sent for slaughter on d 7, 21, and 35, respectively. In contrast to the current study, Hinson et al. (2012a) reported increases in growth rate and feed efficiency with increasing RAC feeding durations. In the current study, feeding RAC reduced ADFI and this reduction increased with time on RAC, which contributed to the greater feed efficiency as time on RAC increased. However, this has not been observed in other studies of similar study design (Hinson et al., 2012a; Christianson et al., 2014; Gerlemann et al., 2014). Collectively, these results, along with others, suggest that, while RAC consistently improves overall growth rate and feed efficiency, the greatest improvement is observed soon after RAC implementation, and may decline after 21 d of feeding.

Although the effect of marketing strategy was not directly evaluated in the current study, ADG and ADFI of pigs was generally lowest in Phase 1, when floor space and feeder space were most restrictive (Table 3). After Phase 1, ADG and ADFI were greater in both control and RAC-fed pigs during Phase 2, with the ADG of controls being 20.0% greater in Phase 2 compared to Phase 1. Interestingly, the removal of 16% of pigs from the RAC-fed pens on d 7 did not produce a substantial response in subsequent growth rate during phase 2 (d 7 to 21). Whether it was due to remaining floor space still being restrictive or due to maximal growth rates already being achieved remains unclear. Growth performance in Phase 3 was generally similar to that of Phase 2, suggesting that the additional removal of 10 pigs on d 21, and resulting increase in floor and feeder space, did not further improve growth performance of the remaining pigs in the pen, which is generally in agreement with previous research evaluating effects of removing pigs from a pen on subsequent growth performance of remaining pigs (DeDecker et al., 2005; 2007; Gerlemann et al., 2013).

### Carcass Characteristics

Pigs fed RAC were heavier ($P < 0.001$) at the end of Phase 2 and 3 and for overall end weight (Table 4). Overall, feeding RAC increased ($P < 0.001$) HCW (3.9 kg), which falls within the range reported in previous research (Apple et al., 2007; Puls et al., 2015). In addition, carcass yield (0.7% units), LM depth (4.98%), and predicted lean content (1.0% units) were all increased from feeding RAC, results similar to other studies (Hinson et al., 2012b; Christianson et al., 2014; Gerlemann et al., 2014) whereas backfat depth was reduced ($P < 0.001$; 6.3% lower) compared to controls.

Improvements over controls in carcass yield (0.20, 0.60, and 0.90% units for Phase 1, 2, and 3, respectively) and predicted lean content (0.2, 1.0, and 1.3% units greater for Phase 1, 2, and 3, respectively) from feeding RAC.

### Table 4. Effects of ractopamine hydrochloride (RAC) on the carcass characteristics of heavy-weight finishing pigs sent for slaughter using a 3-phase marketing strategy

| Item                           | RAC inclusion level, mg/kg | 0 | 7.4 | SEM | $P$-value |
|-------------------------------|----------------------------|---|-----|-----|-----------|
| No. of pens                   |                            | 44| 44  |     |           |
| Phase 1 ($d 0$ to $d 7$)²     |                            | 4 | 4   |     |           |
| No. pigs sent for slaughter on $d 7$ |                        | 139.2| 140.8| 0.96 | 0.15      |
| Slaughter live weight, kg     |                            | 104.4| 106.0| 0.58 | 0.08      |
| HCW, kg                       |                            | 75.4| 75.3| 0.13 | 0.28      |
| Carcass yield, %              |                            | 16.4| 16.8| 0.30 | 0.46      |
| LM depth, mm³                 |                            | 74.8| 76.5| 0.67 | 0.01      |
| Predicted lean content, %     |                            | 56.7| 56.9| 0.16 | 0.31      |
| Phase 2 ($d 7$ to 21)³        |                            | 10| 10  |     |           |
| No. pigs sent for slaughter on $d 21$ |                        | 142.5| 147.2| 1.48 | 0.001     |
| Slaughter live weight, kg     |                            | 107.7| 112.2| 1.20 | 0.001     |
| HCW, kg                       |                            | 75.4| 76.2| 0.08 | 0.001     |
| Carcass yield, %              |                            | 16.4| 15.8| 0.11 | 0.01      |
| LM depth, mm³                 |                            | 74.8| 79.1| 0.69 | 0.01      |
| Predicted lean content, %     |                            | 56.5| 57.5| 0.21 | 0.001     |
| Phase 3 ($d 21$ to 35)⁴       |                            | 11| 11  |     |           |
| No. pigs sent for slaughter on $d 35$ |                      | 144.4| 148.2| 1.04 | 0.001     |
| Slaughter live weight, kg     |                            | 108.9| 113.1| 0.50 | 0.001     |
| HCW, kg                       |                            | 75.4| 76.3| 0.25 | 0.002     |
| Carcass yield, %              |                            | 19.3| 17.3| 0.24 | 0.001     |
| LM depth, mm³                 |                            | 73.7| 77.5| 0.27 | 0.001     |
| Predicted lean content, %     |                            | 55.7| 57.0| 0.14 | 0.001     |
| Overall ($d 0$ to 35)⁵        |                            | 142.9| 146.8| 1.20 | 0.001     |
| Slaughter live weight, kg     |                            | 107.8| 111.7| 0.78 | 0.001     |
| HCW, kg                       |                            | 75.4| 76.1| 0.12 | 0.001     |
| Carcass yield, %              |                            | 17.7| 16.6| 0.10 | 0.001     |
| LM depth, mm³                 |                            | 74.8| 78.0| 0.34 | 0.001     |
| Predicted lean content, %     |                            | 56.2| 57.2| 0.07 | 0.001     |

¹Trade name: Paylean, Elanco Animal Health, Greenfield, IN.
²Heaviest ~16% of pigs sent for slaughter on $d 7$.
³Backfat depth and LM depth measured using Animal Ultrasound Services Carcass Value Technology System (Animal Ultrasound Services Inc., Ithaca, NY).
⁴Next heaviest 40% of pigs sent for slaughter on $d 21$.
⁵Final 44% of pigs sent for slaughter on $d 35$.
⁶Weighted average of carcass characteristics for entire 35 d feeding period.
increased with increasing time on RAC. This is likely driven by the sharp reduction in backfat in RAC-fed pigs compared to the control (2.4% greater, 4.0% lower, and 10.4% lower for Phase 1, 2, and 3, respectively).

In the current study, improvements in carcass traits associated with feeding RAC increased with increasing time on feed, which concurs with the results of Hinson et al. (2012a), who reported greater improvements compared to controls for HCW, carcass yield, LM depth, and lean content, as well as decreased backfat depth as RAC feeding duration increased. Additionally, Gerlemann et al. (2014) reported improvements in carcass yield of 0.1, 0.9, and 1.1% units for pigs slaughtered after 7, 21, and 35 d of RAC feeding, respectively. Similarly, Christianson et al. (2014) reported a 0.1% unit lower, 0.7% unit greater, and 0.7% unit greater carcass yield for RAC-fed pigs sent for slaughter on d 7, 21, and 35, respectively, compared to controls. Similar to the current study, these authors reported greater reductions in backfat depth, but greater LM depth, and an increase in predicted lean content as RAC feeding duration increased (Gerlemann et al., 2014; Christianson et al., 2014). The results of this study, along with other previous research, suggest that even in heavy-weight finishing pigs, RAC-induced responses on carcass traits relative to those of controls-fed pigs continue to increase with greater RAC feeding durations.

Conclusions

These results validate the consistent response observed from feeding RAC on increased growth performance, carcass yield, and carcass leanness. Moreover, these results also suggest that with increasing time on RAC, growth rate and feed efficiency will decrease, but improvements in carcass yield and leanness will continue to increase with longer feeding periods in heavy-weight (144 kg) pigs.

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