



Ractopamine Hydrochloride Did Not Impact Carcass Traits, Muscle Fiber Types, or Sensory Traits of Long-Fed Yearling Heifers

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Abstract: Crossbred heifers ($n = 64$; animal was the experimental unit) were assigned to 1 of 8 treatments in a 4×2 factorial arrangement, with 4 treatment days-on-feed (DOF; 79, 100, 121, 142) and 2 levels of ractopamine hydrochloride (RAC) supplementation (0 or $300 \text{ mg} \times \text{hd}^{-1} \times \text{d}^{-1}$). At 24 h postmortem, carcass traits were determined by trained personnel and longissimus samples were removed for muscle fiber type analyses. Boneless strip loins (IMPS #180) were fabricated and vacuum-packaged at 24 h postmortem and aged for 21 d, cut into 2.54 cm thick steaks, then frozen for no longer than 6 mo. After thawing for 24 h, Warner-Bratzler shear force (WBSF) and trained sensory panel analyses were conducted. Marbling was greater ($P < 0.05$) for control (CON; $0 \text{ mg} \times \text{hd}^{-1} \times \text{d}^{-1}$ ractopamine hydrochloride) heifers than RAC heifers fed for either 79 or 100 d, but lower ($P < 0.05$) for CON heifers than RAC heifers fed for either 121 or 142 DOF. Feeding RAC had no effect ($P > 0.05$) on carcass traits, muscle fiber histology, or meat quality. The addition of RAC had no effect ($P > 0.05$) on Warner-Bratzler shear force. Feeding RAC had no negative impacts on carcass traits or meat quality and actually improved marbling scores in longer-fed heifers.

Keywords: beef, fiber types, heifer, ractopamine hydrochloride, sensory, tenderness

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Introduction

In today's market, increasing input costs for beef producers have directed research efforts toward finding more cost-effective production options. Improved methods for decreasing the feed required per unit of gain in live animals are essential to alleviate input costs wherever possible. Heifers comprise one third of the annual United States beef harvest but are less valuable because heifers are less efficient, produce lower carcass weights (hot carcass weight, HCW), and generally are less tender than steers at similar ages (Choat et al., 2006; Tatum et al., 2007). Thus, there is need to devise strategies to improve efficiency and tenderness in growing heifers. The β -agonists have been developed to increase growth rate (average daily gain, ADG) and lean muscle deposition and decrease fat accretion (Mersmann, 1998), resulting in lean muscle growth from muscle fiber hyper-

trophy (Ebarb et al., 2017) and meat animals reaching desired slaughter weights in a shorter amount of time.

Edenburn et al. (2016) reported an increase in the hot carcass weight, dressing percentage, and longissimus muscle area with no impact on marbling or fat thickness of cattle fed ractopamine-HCl (RAC). However, they did not find any advantage of feeding RAC for 41 d compared to 28 d prior to slaughter. Ebarb et al. (2017) reported that feeding $400 \text{ mg} \times \text{d}^{-1} \times \text{heifer}^{-1}$ RAC for the last 28 d prior to slaughter resulted in an increase in the percentage of myosin heavy chain type I along with a drop in the percentage of myosin heavy chain type IIX. Furthermore, they found that heifers fed RAC had an increase in the muscle fiber cross-sectional area of myosin heavy chain type I, IIA, and IIX of 10, 16, and 11%, respectively.

Unfortunately some studies have found negative effects of RAC on tenderness (Howard et al., 2014) of steaks from cattle regardless of days of aging even

out to 35 d (Ebarb et al., 2017). Furthermore, the literature has shown mixed results in the interaction of feeding RAC across days on feed (DOF), as some have reported the growth promotant acts the same regardless of DOF (Edenburn et al., 2016; Vasconcelos et al., 2008; Winterholler et al., 2007), whereas others have reported that carcass and sensory traits vary with DOF when cattle were fed a β -agonist (Sissom et al., 2007). Therefore, the current study was conducted to characterize the effects of RAC on beef quality in heifers, an economically important but understudied aspect of cow-calf operations. We hypothesized that feeding long-fed heifers $300 \text{ mg} \times \text{hd}^{-1} \times \text{d}^{-1}$ RAC would improve lean muscle growth and carcass traits without negatively affecting meat sensory traits.

Materials and Methods

Animals

All experimental procedures performed at Auburn University (from June to October 2008) were approved by the Auburn University Institutional Animal Care and Use Committee (PRN 2007–1273). Sixty-four commercial (British \times British or British \times Continental crosses) crossbred yearling (mean age was 402 d) heifers were purchased from 7 Alabama beef producers for this study and were assigned treatments stratified for weight and hip height. For 66 d prior to the experiment, heifers grazed on summer perennial pasture mixture (bermudagrass: *Cynodon dactylon* and bahiagrass: *Paspalum notatum* Flugge) and were fed soyhull pellets ($3.2 \text{ kg} \times \text{hd}^{-1} \times \text{d}^{-1}$). Following this grazing period, heifers were transported to the Auburn University Beef Cattle Evaluation facility for the remainder of the experiment. Heifers (the experimental unit) were assigned randomly to one pen with Calan gates (American Calan, Northwood, NH) for 1 of 8 treatments in a 4×2 factorial arrangement based on an even distribution of initial body weight (BW) and hip height in each treatment pen. Heifers were fed the finishing diet (Table 1) for either 79, 100, 121, or 142 d ($n = 16$ heifers/DOF), and all diets were supplemented with either 0 (CON) or $300 \text{ mg} \times \text{hd}^{-1} \times \text{d}^{-1}$ RAC (Optaflexx, Elanco Animal Health, Greenfield, IN) for the final 35 d before harvest.

Heifers underwent a 21-d period, prior to experimental feeding, where heifers were acclimated to individual Calan gates for feed intake measurement. During the acclimation period, heifers were fed a diet containing grain (Table 1) at 2% BW. In addition, $0.5 \text{ mg} \times \text{hd}^{-1} \times \text{d}^{-1}$ melengesterol acetate was added

Table 1. Diet Composition fed to yearling heifers¹

Ingredient	Control, %	Supplemented $300 \text{ mg} \times \text{hd}^{-1} \times \text{d}^{-1}$ RAC, %
Cracked Corn	38.5	38.5
Ractopamine HCl	–	0.0025 ^a
Melengesterol acetate	0.000041 ^a	0.000041 ^a
Wheat midds	6.5	6.5
Corn gluten pellets	17.5	17.5
Dried distillers grain	9.5	9.5
Cottonseed hull pellets	10.0	10.0
Cottonseed hulls	5.0	5.0
Limestone	1.25	1.25
Soyhulls	6.5	6.5
Salt	0.5	0.5
Vitamins A,D,E	0.1	0.1
Sodium bicarbonate	1.0	1.0
Trace minerals	0.1	0.1
Monensin ²	0.019	0.019
Molasses	2.5	2.5
Fat	1.0	1.0

^aTop dressed daily 300 mg/hd Ractopamine HCl and 0.5 mg/hd Melengesterol acetate. Percentage of diet assumes 2% BW consumed of a 570 kg heifer.

¹As calculated: DM = 90.15%; CP = 13.66%, NDF = 32.17%, ADF = 15.72, NEm = 1.48 Mcal/kg, NEg = 0.76 Mcal/kg.

²Elanco Animal Health, Greenfield, IN.

to the diet to suppress estrus during the feeding period. Following the acclimation period, heifers had ad-libitum access to water and the diet (either CON or RAC for the final 35 d prior to slaughter) fed twice daily for 79, 100, 121, or 142 d. All heifers were started on feed on the same day and were slaughtered after their experimental DOF. Following each groups' allotted DOF, heifers were transported about 1 km to the Auburn University Lambert-Powell Meat Laboratory 12 to 18 h prior to slaughter. Heifers had access to water during lairage, but no feed. Heifers were restrained and rendered unconscious with a captive bolt gun and humanely slaughtered. Carcasses were not electrically stimulated following harvest and were put into a cooler (4°C).

Carcass evaluation

Following carcass dressing, HCW was recorded. At 24 h postmortem, carcasses were ribbed between the 12th and 13th ribs in order for a trained, experienced carcass evaluator to collect yield grade and quality grade data (USDA, 1997), including longissimus thoracis (LT) area; 12th-rib subcutaneous adjusted fat thickness; percentage kidney, pelvic, and heart fat; and marbling scores (all carcasses were scored as A maturity).

Sample preparation

Following carcass data collection, boneless strip loins (IMPS #180; USDA, 1997) were removed from the right side of the carcass, vacuum-packaged, and aged for 21 d at $4 \pm 2^\circ\text{C}$. Following the aging period, steaks (2.54 cm thick) were cut from each loin starting from the anterior end for sensory analysis and Warner-Bratzler shear force (WBSF) evaluation, vacuum-packaged, and frozen (-10°C) for no longer than 3 mo for analyses.

Histochemical fiber typing

Longissimus thoracis muscle samples from the 12th rib of the right carcass side were removed 24 h postmortem for fiber type analysis according to the technique described by Solomon and Dunn (1988). Fiber type samples were then cut into 1.27 cm \times 0.64 cm slices, frozen in isopentane, submerged in liquid nitrogen, vacuum-packaged, and stored in a -80°C ultra-cold freezer until analysis. Samples were mounted on a cryostat chuck using liquid media freezing gel (TBS Tissue Freezing Medium #H-TFM; Durham, NC) and set for 15 min. Chucks were then mounted onto a Microm HM505E cryostat (Thermo Fisher Scientific, Waltman, MA) set at -20°C , cut 10 μm thick, and placed onto a microscope slide (Fisherbrand Superfrost Excell Microscope Slides, Thermo Fisher Scientific). Four meat sections were cut on the cryostat and placed on slides for each sample to type a representative number of fibers. After slides completed the staining procedure for ATPase and NADH activity, they were removed from the slide holder and allowed to dry before mounting a cover slip using glycerol mounting gel.

Typing of the fibers was performed using a Motic Type 102M microscope (Motic; Richmond, BC, Canada) attached to a computer. Six to eight pictures were taken using the software from the microscope (Motic Images Plus v2.0, Motic North America, Richmond, BC, Canada) from each sample to obtain a representative sample of 75 to 100 muscle fibers for each heifer. The stained fibers were typed as βR (red, oxidative), αR (intermediate, oxidative/glycolytic), or αW (white, glycolytic) by outlining the fibers on the picture. The images were scaled using a micrometer included with the microscope and calibrated for each of the pictures. As the technician outlined the muscle fiber, the computer calculated the area of the fiber in μm^2 .

Warner-Bratzler Shear Force

Warner-Bratzler shear force evaluation was conducted on steaks according to the procedures by the

American Meat Science Association (American Meat Science Association, 1995). Prior to cooking, steaks were thawed for 24 h at $4 \pm 2^\circ\text{C}$. After thawing, steaks were removed from vacuum packages, weighed, and placed on a preheated George Foreman clam-style grill (Model GRV120, Spectrum Brands, Macon, MO). Steaks were cooked to an internal temperature of 70°C and temperature was monitored using an Electro-Therm Digital thermometer (Model TM99A, Cooper Instruments Corp., Middlefield, CT). Steaks were then placed on a Styrofoam tray, overwrapped with PVC film, and transferred back into a refrigerator ($4 \pm 2^\circ\text{C}$) to cool for 24 h. Following cooling, 6 cores (1.27 cm diameter) were then taken from each steak parallel to the muscle fibers. Warner-Bratzler shear force was measured on each core using a TA.XT2 Texture Analyzer (Texture Technologies Corp., Scarsdale, NY) equipped with a Warner-Bratzler probe and guillotine set using a 50 kg load cell. The probe was programmed to be lowered 30 mm after detection of resistance, whereas the pre-test speed of 2.0 mm/s, penetration speed of 3.3 mm/s, and post-test speed of 10 mm/s was utilized during shearing. Each core was sheared individually perpendicular to the muscle fibers in the middle avoiding connective tissue to determine peak force (kg). An average of 6 cores for each steak was used for statistical analyses.

Trained sensory evaluation

Sensory evaluation was conducted by a 7-member trained sensory panel made up of Auburn University graduate students and faculty experienced in sensory evaluation and trained for 14 d as described by Cross et al. (1978). Trained sensory panels were performed over a 3 wk period. Steaks were thawed at $4 \pm 2^\circ\text{C}$ for 24 h, removed from the vacuum package, and cooked to an internal temperature of 70°C on a preheated George Foreman clam-style grill (Model GRV120, Spectrum Brands, Inc., Macon, MO). Cooked steaks were trimmed of subcutaneous fat and cubes (1 cm^3) were cut and placed in a serving tray. Trays were kept in an incubator, preheated to 65°C until all samples were prepared and panelists began evaluation.

Panelists were seated in individual sensory booths, which included a red incandescent light overhead. A cup of water and non-salted crackers were also included in individual cubicles for panelists to cleanse their palates. Panelists evaluated no more than 8 samples per day to avoid fatigue. Panelists were asked to evaluate 2 samples from each steak for initial and sustained juiciness, initial and sustained tenderness, and flavor intensity on an 8-point hedonic scale with

1 = extremely dry, tough, bland and uncharacteristic of beef, and 8 = extremely juicy, tender, intense, and characteristic of beef, respectively.

Statistical analyses

Data were analyzed using the general linear models procedure in SAS (SAS Inst. Inc., Cary, NC). The experiment was set up as a completely randomized design with heifer as the experimental unit. Fixed effects in this experiment were RAC supplementation (0 or 300 mg \times hd⁻¹ \times d⁻¹) and DOF (79, 100, 121, 142). For sensory analysis, panelist effects were tested and found to be an insignificant ($P > 0.05$) source of variation and therefore panelist scores were averaged. Least squares means were separated with Fishers protected LSD using the PDIF option of SAS for significant main and interaction effects. A significant level of 5% was set for all analyses.

Results

Carcass traits

No interaction effects were significant ($P > 0.1$) for carcass characteristics. Initial weights were similar ($P = 0.39$; Table 2) among treatment groups. Ractopamine supplementation did not ($P > 0.24$) have significant ef-

fects on final weights or carcass characteristics. As expected, final live body weights were lightest ($P < 0.05$) in DOF group 79 and heaviest ($P < 0.05$) in DOF groups 121 and 142. Hot carcass weights were heavier ($P < 0.05$) for heifers fed 100, 121, and 142 d compared to 79 d. Backfat thickness was lower ($P < 0.05$) in heifers fed 79 and 100 d compared to 121 and 142 d. Days on feed did not affect ($P > 0.05$) LT area; however, because carcasses from heifers fed for 79 and 100 d had less ($P < 0.05$) adjusted 12th rib fat thickness, this resulted in lower ($P < 0.05$), yield grades than carcasses from heifers fed 121 and 142 DOF. Marbling scores were greater ($P < 0.05$) in CON than RAC heifers for 79 and 100 d; however, as DOF increased from 100 to 142 d, RAC-fed heifers deposited more ($P < 0.05$) marbling than CON-fed heifers (Fig. 1). Final Quality Grades (Fig. 2) were higher for CON than RAC at 79 DOF, but at 142 DOF RAC was higher than CON ($P < 0.05$)

Muscle fiber types

There was neither a RAC main effect ($P > 0.73$) nor a RAC by DOF interaction effect ($P > 0.23$) for muscle fiber type area or percentages of fiber types within the LT. Even though intermediate fiber types were larger ($P < 0.05$) in the LT of heifers fed 121 d than 100 d, red and white fiber type areas were not affected ($P = 0.10$) by DOF (Table 3). Conversely, the proportion of red

Table 2. Least squares means \pm SEM of carcass characteristics for heifers as influenced by RAC across 5 d on feed (DOF)

Variable	Ractopamine		SEM	$P > F$	DOF				SEM	$P > F$
	CON ¹	RAC ²			79	100	121	142		
No. An. ³	32	32		–	16	16	16	16		
In. Wt ⁴ , kg	430.9	433.0	14.9	0.39	436.3	435.6	434.3	433.4	20.4	0.78
Final Wt ⁵ , kg	570.4	577.1	20.5	0.25	532.4 ^a	566.1 ^{ab}	584.6 ^b	588.7 ^b	28.1	0.011
HCW ⁶ , kg	345.9	351.1	13.0	0.49	321.4 ^a	345.6 ^b	362.1 ^b	364.8 ^b	18.0	0.002
BF ⁷ , cm	1.80	1.70	0.05	0.91	1.34 ^a	1.32 ^a	2.00 ^b	2.31 ^b	0.07	< 0.001
LT area ⁸ , cm ²	85.9	85.8	1.94	0.52	81.9	85.2	86.5	89.6	1.94	0.54
KPH ⁹ , %	3.40	3.34	0.12	0.84	2.25 ^a	3.60 ^{ab}	3.95 ^b	3.66 ^b	0.2	< 0.001
YG ¹⁰	3.54	3.56	0.2	0.99	2.91 ^a	3.17 ^a	4.03 ^b	4.10 ^b	0.3	0.002

^{a,b}Means within a row and within a main effect lacking a common superscript differ significantly ($P < 0.05$).

¹CON = no ractopamine supplementation.

²RAC = 300 mg \times hd⁻¹ \times d⁻¹ ractopamine.

³Number of animals.

⁴Initial weight.

⁵Final weight.

⁶Hot carcass weight.

⁷Backfat thickness measured 3/4 of the way along the longissimus muscle at the 12th rib.

⁸Longissimus thoracis muscle area measured at the 12th rib.

⁹Kidney, pelvic, and heart fat.

¹⁰USDA Yield Grade.

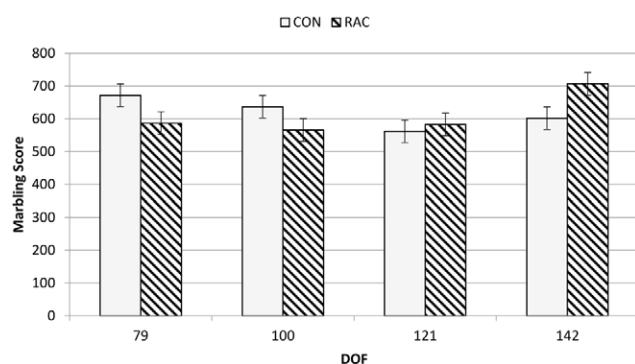


Figure 1. Least Squares Means of marbling scores in yearling heifers as affected by RAC across 4 d on feed. Marbling scores were determined according to the USDA grading standards using a scale of: traces = 200–299; slight = 300–399; small = 400–499; modest = 500–599; moderate = 600–699; slightly abundant = 700–799; moderately abundant = 800–899; abundant = 900–999. Interaction $P = 0.027$.

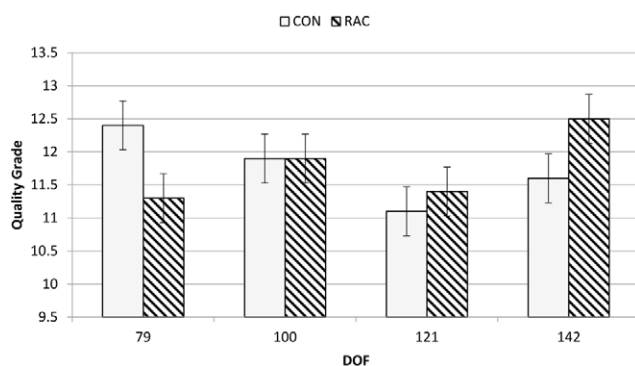


Figure 2. Least Squares Means of USDA Quality Grades in yearling heifers as affected by RAC across 4 d on feed. Quality Grade scores were determined according to the USDA grading standards using a scale of: 8 = High Standard, 9 = Low Select, 10 = High Select, 11 = Low Choice, 12 = Average Choice, 13 = High Choice, 14 = Low Prime. Interaction $P = 0.022$.

fiber type was lowest ($P < 0.05$) in the LT of heifers fed 79 and 100 d compared to 121 d, whereas the LT from heifers fed 121 d had the lowest ($P < 0.05$) proportion of white fibers (28%) compared to the LT from heifers fed 79 or 100 d. Additionally, red fiber type percentage was intermediate in value in samples taken from heifers fed 142 d compared to the LT from heifers fed 79 or 100 d. The percentage of intermediate fibers in the muscle was not different across DOF ($P = 0.17$).

Sensory evaluation and Warner-Bratzler Shear Force

Feeding RAC had no effect ($P = 0.13$; Table 4) on initial and sustained juiciness, initial and sustained tenderness, and flavor intensity. Shear force values were not affected ($P > 0.25$) by DOF, RAC, or their interaction.

Discussion

Carcass traits

Repartitioning agents, such as RAC, that are administered to food animals are expected to decrease carcass adiposity while increasing LT area (Mersmann, 1998). In this regard, the potential effect of feeding RAC on carcass traits has been investigated previously in calf-fed steers and heifers (Woerner et al., 2011). This has shown mixed effects as some research has shown little impact on repartitioning while others have shown significant effects. Walker et al. (2006) demonstrated that feeding RAC had no effect on LT area, 12th rib fat thickness, USDA yield grade and marbling scores, but increased HCW and internal fat

Table 3. Least squares means \pm SEM of mean fiber type areas (μm^2) and fiber type percentages for heifers across days on feed (DOF)

Variable	Ractopamine		SEM	$P > F$	DOF				SEM	$P > F$
	CON ¹	RAC ²			79	100	121	142		
Muscle fiber area, (μm^2)										
Red	2503.0	2530.1	92.2	0.83	2365.5	2352.7	2674.6	2715.9	132	0.10
Intermediate	3288.0	3250.9	125.1	0.83	3341.3 ^{ab}	2917.8 ^a	3672.5 ^b	3304.3 ^{ab}	179	0.02
White	4265.8	4200.9	156.7	0.77	4243.4	4085.2	4708.8	4163.8	225	0.77
Muscle fiber type, %										
Red	37.3	37.9	1.37	0.74	34.3 ^a	34.1 ^a	43.7 ^b	40.9 ^{ab}	2.1	0.001
Intermediate	29.3	29.0	1.06	0.84	30.5	31.1	28.2	27.4	1.9	0.17
White	33.4	33.1	1.20	0.85	35.2 ^b	34.8 ^b	28.0 ^a	31.7 ^{ab}	2.0	0.03

^{a,b}Means lacking a common superscript within a row differ significantly ($P < 0.05$).

¹CON = no ractopamine supplementation.

²RAC = 300 mg \times hd⁻¹ \times d⁻¹ ractopamine.

Table 4. Least squares means of sensory evaluation as affected by RAC supplementation

Variable	Ractopamine		SEM	<i>P</i> > <i>F</i>	Days on feed				SEM	<i>P</i> > <i>F</i>
	CON ¹	RAC ²			79	100	121	142		
	Initial Juiciness ³	5.23			5.18	0.056	0.21	5.19		
Sustained Juiciness ³	5.06	5.05	0.058	0.28	4.84	4.85	5.14	5.33	0.175	0.084
Initial Tenderness ³	5.34	5.12	0.057	0.89	5.25	5.24	5.40	5.39	0.133	0.42
Sustained Tenderness ³	5.22	5.05	0.059	0.81	5.04	5.01	5.39	5.46	0.150	0.67
Flavor Intensity ³	4.82	4.74	0.055	0.13	4.50	4.66	4.83	4.57	0.124	0.18
WBS, kg	3.42	3.29	0.105	0.39	3.33	3.34	3.29	3.46	0.175	0.85

¹CON = no ractopamine supplementation.

²RAC = 300 mg × hd⁻¹ × d⁻¹ ractopamine.

³Tenderness, Juiciness, and flavor intensity were evaluated using an 8-pt. hedonic scale where 1 = extremely tough, dry, and bland, respectively, and 8 = very tender, juicy, and intensely flavorful, respectively.

content. In addition, Schroeder et al. (2004a) reported that RAC supplementation increased HCW without impacting fat thickness, LT area, marbling, yield grade, and quality grade when fed to feedlot heifers. Edenburn et al. (2016) reported significant increases in final BW due to RAC supplementation, but found no differences for DMI, ADG, or G:F. Consistent with previous studies (e.g., Talton et al., 2014), no differences in LT area, 12th-rib fat thickness, HCW, or USDA yield grade, were observed in response to feeding RAC in the current study. Quinn et al. (2008) also reported that no differences existed in HCW and other carcass characteristics in response to feeding 200 mg × hd⁻¹ × d⁻¹ of RAC to growing heifers. Likewise, several more reports showed there were no significant differences in carcass traits for animals treated with RAC (Winterholler et al., 2007; Gruber et al., 2007; Strydom et al., 2009). Lean et al. (2014), in a meta-analysis of experiments from 2003 to 2013, reported a standardized mean increase of 0.47 in HCW and a 0.11 decrease in marbling score from feeding ractopamine hydrochloride to cattle. The lack of an effect of RAC on carcass characteristics in the current study is similar to these previous studies where minimal effects were found in efficiencies of gain besides gains in BW.

In general, it is understood that as the DOF increases, carcass traits reflect an increase in fat deposition in subcutaneous, intermuscular, and intramuscular fat. Dolezal et al. (1982) reported that 200 DOF and McKeith et al. (1985a) indicated that 224 DOF were necessary for steers to deposit sufficient marbling to grade Choice, whereas May et al. (1992) found that only 112 DOF was necessary to reach a Small amount of marbling. Because of the advanced finish (1.0 cm of backfat determined by ultrasound; data not shown) of the cattle when the current study was initiated, all cattle, regardless of DOF, likely had at least a Small amount of marbling present in the LT.

Rathmann et al. (2012) reported a significant reduction in ADG and feed efficiency as heifers were fed beyond 127 DOF, which was reflected in a reduction of weight rate of gain and final body weight beyond that point. Similar results were present in the current study in which very limited increases in HCW were seen beyond 121 DOF. This likely is a sign that the animals were nearing the top of their growth curve (Dikeman, 2013) and very little weight was added to the HCW except what would be expected as a result of increased backfat thickness over the carcass and relatively small increases in LT area from the beginning of the DOF.

Muscle fiber types

Ractopamine hydrochloride supplementation of heifers in this study had no impact on the muscle fiber area, nor muscle fiber type distribution. Fiber type results in this experiment differ from other studies that reported that RAC supplementation affected both fiber type area and percentages. Strydom et al. (2009) reported no difference in red fiber area which concurs with the present study, but these researchers found an increase in both intermediate and white fiber type size in the LT of steers supplemented with 300 mg × hd⁻¹ × d⁻¹ RAC. Strydom et al. (2009) reported that RAC supplementation did not affect fiber type distribution in the LT of steers, and Gonzalez et al. (2010) found no difference in the fiber size or distribution of any of the muscles of the loin or round. This contrasts with Ebarb et al. (2017) who showed that feeding 400 mg × d⁻¹ × hd⁻¹ RAC for the last 28 d prior to slaughter resulted in an increase in the percentage of myosin heavy chain type I along with a drop in the percentage of myosin heavy chain type IIX. Furthermore, they found that heifers fed RAC had an increase in the muscle fiber cross-sectional area of myosin heavy chain type I, IIA, and IIX of 10, 16, and 11%, respectively.

Warner-Bratzler Shear Force

Gruber et al. (2008) reported greater WBSF values for steers treated with a lower dose of $200 \text{ mg} \times \text{hd}^{-1} \times \text{d}^{-1}$ of RAC (compared to $300 \text{ mg} \times \text{hd}^{-1} \times \text{d}^{-1}$ used in the current study) compared to CON steers, whereas Avendaño-Reyes et al. (2006) reported an increase in WBSF in steaks from steers supplemented with $300 \text{ mg} \times \text{hd}^{-1} \times \text{d}^{-1}$ RAC. Schroeder et al. (2004b) reported no differences in WBSF for cattle treated with 100 and 200 $\text{mg} \times \text{hd}^{-1} \times \text{d}^{-1}$ RAC, but greater WBSF at a $300 \text{ mg} \times \text{hd}^{-1} \times \text{d}^{-1}$ RAC dosage. In the current study, shear force measurements were not influenced by RAC. This is consistent with Quinn et al. (2008) and Strydom et al. (2009), who showed no effect of RAC on WBSF values when cattle were fed at a dosage of $200 \text{ mg} \times \text{hd}^{-1} \times \text{d}^{-1}$. Strydom et al. (2009) also showed no differences in shear force for control and RAC treatment in feedlot steers. In a meta-analysis of studies that fed RAC, Lean et al. (2014) reported a standardized mean increase of WBSF of 0.41 kg due to feeding RAC. While the literature is inconsistent on this point, our data indicate that RAC administration does not adversely affect tenderness in heifers.

The present study found that DOF did not impact WBSF measurements. This finding agrees with previous studies (Tatum et al., 1980; McKeith et al., 1985b; Van Koevinger et al., 1995). Additionally, Zinn et al. (1970) reported that WBSF in the longissimus muscle decreased through 150 DOF, but leveled off after that point. It is likely that in the present study, the advanced finish of the heifers entering the study negated the impact of DOF on the WBSF and tenderness of LT muscle.

Sensory evaluation

Gruber et al. (2008) fed cattle of different biological types $200 \text{ mg} \times \text{hd}^{-1} \times \text{d}^{-1}$ RAC and found that sensory tenderness ratings were reduced in beef from RAC-fed cattle. Similarly, Schroeder et al. (2004b) reported there were no differences in tenderness ratings for cattle fed a RAC dosage below $300 \text{ mg} \times \text{hd}^{-1} \times \text{d}^{-1}$; yet, cooked steaks tenderness was reduced when cattle were fed $300 \text{ mg} \times \text{hd}^{-1} \times \text{d}^{-1}$. The differences between $300 \text{ mg} \times \text{hd}^{-1} \times \text{d}^{-1}$ -treated and control steaks were small enough as to be non-detectable by consumers. Therefore, it was concluded that RAC administration had no effect on palatability characteristics.

Past studies have shown that β -agonists like zilpaterol had a negative effect on tenderness attributes as measured by shear force and sensory evaluation. However, studies comparing RAC effects may not exhibit the same negative results on tenderness as zilpa-

terol. Rathmann et al. (2012) and Shook et al. (2009) reported that heifers and steers, respectively, fed 8.33 mg/kg DM zilpaterol hydrochloride had greater longissimus muscle shear force at 7, 14, and 21 d postmortem compared to heifers and steers not fed zilpaterol hydrochloride. These β_2 -agonists have been shown to increase levels of calpastatin, which, in turn, results in decreased postmortem muscle protein degradation (Koochmaraie et al., 1991). Such an increase in muscle calpain protease inhibitors would be expected to result in decreased postmortem muscle protein degradation and a perceived decrease in tenderness (Koochmaraie et al., 1991). Ractopamine is classified as a β_1 -agonist (Mersmann, 1998) and the results of the current study suggests that β_1 -agonists do not impart negative effects on beef tenderness as β_2 -agonists.

Conclusion

Results of the present study indicate that heifers can be fed RAC at a dosage of $300 \text{ mg} \times \text{hd}^{-1} \times \text{d}^{-1}$ 35 d before slaughter without producing detrimental effects on carcass traits or sensory attributes. Increasing DOF had a more dramatic effect on carcass traits than RAC supplementation, and feeding heifers beyond 121 d does not result in additional benefits in carcass or sensory characteristics.

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