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PRODUCTION AND MANAGEMENT: *Original Research*

Evaluation of coated steroidal combination implants on feedlot performance and carcass characteristics of beef heifers fed for constant or varying days on feed

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ABSTRACT

Objective: Two experiments evaluated the effects of delayed, long-lasting implant strategies for finishing heifers fed for constant or varying days on feed.

Materials and Methods: In Exp. 1, heifers (n = 500; initial BW = 280 ± 21 kg) were allotted randomly to 1 of 5 treatments, including no implant (CON), Revalor-XH on d 1 (XH), Revalor-200 on d 1 (E200), Revalor-XR on d 1 (XR), or Revalor-200 on d 70 (D200). All implants contained 200 mg of trenbolone acetate and 20 mg of estradiol. In Exp. 2, 720 heifers (initial BW = 281 ± 10 kg) were assigned randomly to treatments in a 3 × 4 factorial arrangement, with 3 implant treatments [no implant (NCON), Revalor-200 on d 1 and 100 (PCON), or Revalor-XH on d 1 (XH)] and 4 serial slaughter dates following 151, 165, 179, or 193 d on feed.

Results and Discussion: In Exp. 1, implanted heifers were heavier, gained more, and were more efficient ($P \leq 0.03$) compared with CON heifers, but no differences were observed among implant treatments ($P \geq 0.21$) over the 198-d finishing trial. Implanted heifers had greater hot carcass weight but lower marbling scores compared with CON heifers ($P \leq 0.04$). In Exp. 2, there were no serial slaughter × implant treatment interactions for growth performance ($P \geq 0.23$) or carcass characteristics ($P \geq 0.31$). Final BW, fat thickness, and numerical YG increased linearly ($P < 0.01$), whereas ADG ($P = 0.01$) and G:F ($P = 0.02$) decreased linearly, with increasing days on feed.

Implications and Applications: Hot carcass weight was increased by implanting strategy and increasing days on feed, but aggressive initial implants did not improve performance.

Key words: feedlot, heifers, implant payout, serial slaughter

INTRODUCTION

Growth-promoting implants have been proven to be a safe and effective tool in the feedlot industry to increase ADG and hot carcass weight (**HCW**) in steers and heifers (Duckett and Owens, 1997; Bruns et al., 2005; Folmer et al., 2009). Implants elicit this response by increasing frame size and delaying fattening, which requires cattle to be fed to longer days on feed (**DOF**) to achieve similar empty body fat percentage as nonimplanted cattle (Reinhardt, 2007; Smith et al., 2017).

Traditional, uncoated combination implants release hormones over the duration of 60 to 120 d (Mader, 1998), which then requires reimplantation if cattle are fed for over 120 d. More recently, beef producers have been feeding for longer DOF, which can cause problems with facilities and management at the time of reimplant. The FDA has approved coated implants in the last decade that can be used for cattle fed for 200 d after implantation. Coating technology on these implants can delay the partial or entire dose of steroids until approximately 70 to 80 d after implantation, which can deliver similar performance as a traditional initial implant given on arrival followed by a terminal implant approximately 100 d before slaughter. Nichols et al. (2014) reported no differences in final BW, ADG, G:F, or carcass characteristics for steers given either an initial implant and terminal implant or one partially coated implant of the same hormonal concentration and fed for 157 d. Therefore, the objective of this study was to compare feedlot performance and carcass characteristics of long-fed heifers treated with a new partially coated

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(Revalor-XH, Merck Animal Health, De Soto, KS) or fully coated (Revalor-XR, Merck Animal Health) implant program, traditional implant strategies, or no implant and fed for similar or varying DOF.

MATERIALS AND METHODS

All procedures used in these experiments were reviewed and approved by the University of Nebraska–Lincoln Institutional Animal Care and Use Committee.

Experimental Design and Procedures: Exp. 1

Crossbred heifers (n = 500) were used in a randomized block design, with blocks based on trial initiation date (May 20, 2016, or May 27, 2016) and BW (light or heavy initial BW). Heifers were allotted randomly to pens (10 heifers per pen), and pens were assigned randomly to 1 of 5 treatments (10 pens per treatment): (1) no implant (**CON**); (2) Revalor-XH [200 mg of trenbolone acetate (**TBA**)/20 mg of estradiol (**E2**), partially coated; Merck Animal Health] on d 1 (**XH**); (3) Revalor-200 (200 mg of TBA/20 mg of E2, noncoated; Merck Animal Health) on d 1 (**E200**); (4) Revalor-XR (Merck Animal Health) on d 1 (**XR**); or (5) Revalor-200 (Merck Animal Health) on d 70 (**D200**). All implants contained 10 pellets (20 mg of TBA/2 mg of E2 per pellet), but coating technology varied among implants. Revalor-XR contained 10 coated pellets that are designed to be released approximately 70 to 80 d after implanting, whereas Revalor-XH contains 4 uncoated pellets (80 mg of TBA/8 mg of E2) for immediate release and 6 coated pellets (120 mg of TBA/12 mg of E2) to release approximately 70 to 80 d after implanting.

Heifers were sourced from auction markets and transported to the University of Nebraska Eastern Research and Extension Center research site located near Mead, Nebraska. At the time of feedlot arrival, all heifers were individually identified (panel tag, electronic button, and metal clip). Then, heifers received an infectious bovine rhinotracheitis virus, parainfluenza-3 virus, bovine viral diarrhea virus (types I and II), bovine respiratory syncytial virus, *Mannheimia haemolytica*, and *Pasteurella multocida* combination vaccine (Vista Once, Merck Animal Health); a *Clostridium chauvoei*, *specticum*, *novyi*, *sordellii*, *perfringens* Types B, C, and D bacterin-toxoid (Vision 7, Merck Animal Health); a 10% fenbendazole oral suspension for the control of lung worms, stomach worms, and intestinal worms (Safe-Guard Dewormer, Merck Animal Health); a synthetic prostaglandin to induce luteolysis (Estrumate, Merck Animal Health); and 1% doramectin injectable for treatment and prevention of gastrointestinal and external parasite issues (Dectomax, Zoetis Inc., Florham Park, NJ).

Before initiation of the trial, heifers were limit fed (2% of BW) a diet consisting of 50% Sweet Bran (Cargill Corn Milling, Blair, NE) and 50% alfalfa hay (DM basis) for 5 d to minimize variation in gastrointestinal fill (Watson et al., 2013). Heifers were weighed (Silencer Squeeze Chute; Moly Mfg. Inc., Lorraine, KS) 2 consecutive days (d 0 and 1) to establish initial BW. Heifers were stratified by BW and blocked by d 0 BW (light and heavy) based on weights not being more variable than 45 kg within a BW block. Heifers were allotted to pens within each block. Initiation of trial was also used as a blocking criteria, with 2 starting dates 1 week apart and 25 pens starting each week. Pens were assigned randomly to 1 of 5 treatments with 10 pens/treatment. Blocking criteria (4 total blocks with unequal replications) included both BW and start date (group). Light and heavy BW blocks consisted of 4 and 1 replications for group 1, respectively. In start group 2, 1 replication and 4 replications were used for light and heavy blocks, respectively. On d 1 (May 20, 2016, and May 27, 2016, for groups 1 and 2, respectively), heifers were implanted with their respective treatment. Implants were administered in the middle one-third of the ear using a Revalor implant gun (Merck Animal Health). In each pen, 3 heifers with an average initial BW closest to the mean pen BW were selected for blood collections via tail venipuncture (Vacutainer Serum tubes; BD, Franklin Lakes, NJ) on d 1, 35, 70, 105, 140, and 175 of the feeding trial. If tail venipuncture was unsuccessful, jugular venipuncture was used. Whole blood samples were allowed to clot at 4°C for 24 h before sera harvest to be used for quantifying circulating concentrations of BUN, nonesterified fatty acid concentration (**NEFA**), IGF-1, and 17β-trenbolone (**17β-TbOH**). On blood collection dates, cattle were also individually weighed in the morning before feeding to establish interim performance.

All heifers were adapted to a common finishing diet over a 24-d period consisting of 4 adaptation diets. The amount of wet distillers grains, Sweet Bran (Cargill, Blair, NE), and supplement were held constant at 15, 25, and 4% (DM) of the diet, respectively. The amount of dry-rolled corn (**DRC**) and high-moisture corn (**HMC**) were gradually increased at the expense of alfalfa hay. The first adaptation diet consisted of 11% DRC, 0% HMC, and 45% alfalfa hay and was fed for 5 d. The second adaptation diet was fed for 5 d and consisted of 18.3% DRC, 2.8% HMC, and 35% alfalfa hay. The third adaptation diet included 23.3% DRC, 7.7% HMC, and 25% alfalfa hay and was fed for 7 d. The fourth and final adaptation diet included 28.3% DRC, 12.7% HMC, and 15% alfalfa hay and was fed for 7 d. The finishing diet included 32.3% DRC, 16.2% HMC, and 7.5% grass hay, replacing alfalfa hay.

Heifers were housed in open feedlot pens with approximately 91 cm of linear bunk space and 56 m^2 pen space per heifer. Feed bunks were assessed once daily at approximately 0600 h for presence of feed. Feed amounts were increased or decreased daily to maintain an ad libitum bunk management approach. Cattle were fed once daily between 0700 and 0900 h and had ad libitum access to fresh water and feed. Diets were mixed and delivered using a truck-mounted feed mixer and delivery unit with scale breaks of 0.5 kg (Roto-Mix model 420, Roto-Mix, Dodge City, KS). All scales (cattle weights and feed trucks) were calibrated

within 3 mo of experiment initiation. Weekly samples of ingredients were collected by university personnel, composited by month, and sent to a commercial laboratory (Ward Laboratories Inc., Kearney, NE) to determine CP (Padmore, 1990a,b; Gavlak et al., 1996; LECO Corporation, St. Joseph, MI), NDF (Mertens, 1992; Ankom Technology, 1998), calcium (Campbell and Plank, 1991; Kovar, 2003), and phosphorus (Campbell and Plank, 1991; Kovar, 2003; Wolf et al., 2003) content of individual ingredients. When refusals were present, orts were weighed, sampled, and frozen for later analysis of DM. Dry matter of orts was determined by placing samples in a 60°C forced-air oven for 48 h (AOAC method 935.29; AOAC International, 1999). Cattle were visually evaluated daily by trained University of Nebraska–Lincoln personnel. Evaluations include proper functionality of water tanks, integrity of fences and feed bunks, and any abnormal behavior of the cattle. When heifers were determined to be sick, they were removed from the pen and taken to the processing facility for diagnosis and appropriate treatment before returning to their home pen.

On day of shipping, heifers were offered 50% of the previous day's intake. In the afternoon, all heifers were brought to the handling facility, pen weighed to determine final live BW, and loaded onto trucks. Heifers were slaughtered at a commercial beef packing facility (Greater Omaha Packing, Omaha, NE) after 194 d (block 1) or 201 d (block 2) on feed. Hot carcass weight and liver scores were recorded at slaughter, and LM area, 12th rib fat thickness, and USDA marbling scores were recorded after a 48-h chilling period. Yield grade was calculated (USDA, 2016) from the following formula: 2.5 + (0.98425 × 12th rib fat, cm) + [0.2 × 3.0(KPH, %)] + (0.00837 × HCW, kg) − (0.0496 × LM area, cm^2). Live final BW was pencil shrunk 4% to calculate DP and live performance. A common DP of 63% was used to calculate carcass-adjusted final BW, ADG, and G:F.

Serum Metabolite Analysis

Whole blood samples were centrifuged at 1,250 × *g* for 20 min at 4°C. Serum was then harvested from each centrifuge tube, with two 2-mL tubes frozen at −20°C for BUN and NEFA analyses, and another 2-mL tube frozen at −80°C for IGF-1 and 17β-TbOH analyses.

Urea-N was analyzed using sera by animal and day using an adapted procedure from Smith and Murphy (1993), quantified using spectrometry, and fitted to a standard curve. Standard curve was between 0 and 30 mg/dL. Nonesterified fatty acid was analyzed using an in vitro enzymatic colorimetric method assay (HR Series NEFA-HR, Wako Pure Chemical Industries Ltd., Mountain View, CA) and quantified using spectrometry fitted to a standard curve. The standard curve was constructed from values ranging from 0 to 1,000 mEq/L. All samples were run in duplicate and were considered for re-runs if the CV between duplicates was greater than 10%.

Serum IGF-1 was quantified via ELISA (Quantikine Human IGF-I ELISA, R & D Systems, Minneapolis, MN). The IGF-I assay was analyzed using sera pooled by pen and day. Before analysis raw sera samples were extracted to reduce IGF binding protein interference. The standard curve constructed for the IGF-I assay was between 9 and 600 ng/mL. Samples were run in duplicate, and determinations were considered for re-runs if the CV between duplicate samples were greater than 10%.

Circulating 17β-TbOH concentration was quantified via liquid chromatography-tandem mass spectrometry using slight modifications to the procedures described by Blackwell et al. (2014). The 17β-TbOH assay was conducted using sera pooled by pen and day, whereas sera from all heifers in CON were pooled by block and day. In 15-mL conical screw-top tubes, equal volumes of methyl-tert-butyl-ether and sera (2 mL) were spiked with 10 ng of internal standard (17β-trenbolone-d3, National Institute for Public Health and the Environment of the Netherlands, Bilthoven, Netherlands) and then placed in an orbital shaker at 300 rpm for 30 min at room temperature. Samples were centrifuged at room temperature for 5 min at 1,500 × *g* to separate sera and methyl-tert-butyl-ether layers. The methyl-tert-butyl-ether layer was transferred to 100 × 16 mm borosilicate glass tubes and evaporated to dryness at 35°C under a gentle stream of nitrogen. Samples were reconstituted in 4 mL of HPLC-grade 80:20 methanol:water (Fisher Scientific, Hampton, NH) before 3 mL of HPLC-grade hexane (Fisher Scientific) was added to the reconstituted samples and vortexed for 30 s. Samples were then centrifuged for 5 min at 1,500 × *g* at room temperature, and the hexane layer was discarded before the hexane wash was repeated. Samples were then dried to a volume of less than 0.5 mL under a gentle stream of nitrogen at 5°C, and 3 mL of 5:95 methanol:water (containing 0.1% Na_4OH) was added to each sample. Oasis MAX cartridges (3cc/60 mg; Waters Corp., Milford, MA) were conditioned with 3 mL of methanol and 3 mL of 5:95 methanol:water + 0.1% Na_4OH, samples were passed through cartridges, and cartridges were washed twice with 3 mL 5:95 methanol:water (containing 0.1% Na_4OH). Cartridges were then allowed to dry under vacuum for 10 min, and samples were eluted into clean 16 × 100 mm borosilicate glass tubes with 7 mL of methanol before samples were evaporated to dryness at 35°C under a gentle stream of nitrogen and reconstituted in 100 μL of 60:40 methanol:water. Reconstituted samples were then passed through a 0.45-μ*M* polypropylene filter into fixed-insert microvials, capped, and stored at −20°C until analysis. Blank (n = 3) and spiked (n = 3) matrix (bovine serum, Sigma-Aldrich, St. Louis, MO) samples were analyzed along with 42 "unknowns" per sample batch (48 extractions in total) to monitor extraction method performance. No steroids were observed above the limit of detection in any solvent or matrix blank. The mean matrix spike recovery (n = 18) for sera was 112.3 ± 20.79%.

Quantification of 17β-TbOH was performed via triple quadrupole liquid chromatography-tandem mass spectrometry (TSQ Endura, Thermo Fisher Scientific Inc., Waltham, MA). Chromatography was performed using a methanol:water gradient elution taken from Blackwell et al. (2013) and a Gemini-NX C18 column (150 × 2.0 mm; Phenomenex, Torrance, CA) with a sample injection volume of 10 μL. Ionization was performed using atmospheric pressure chemical ionization in positive mode. Solvent blanks and check standards were included every 8 and 16 samples, respectively, in instrument runs for quality control purposes. The limit of quantification (25 pg/mL) was determined by the lowest calibration standard included in sample runs, and values below the limit of quantification were assigned a value of 12.5 pg/mL serum, which was half the value of the lowest calibration standard.

Statistical Analysis: Exp. 1

Animal performance and carcass characteristics were analyzed as a randomized block design using PROC MIXED (SAS, Version 9.4; SAS Institute Inc., Cary, NC) with pen as the experimental unit. Heifers that were removed or died during the experiment were not included in the analysis. The model included treatment and block as fixed effects. Treatment means were separated using the pdiff option when the overall *F*-test was significant, and LSM are reported. Quality grade and YG distributions were analyzed using PROC GLIMMIX using a multinomial approach.

Blood urea-N, NEFA, 17β-TbOH, IGF-1, and estradiol-17β were analyzed using PROC GLIMMIX in SAS. Treatment, time, and the treatment × time interaction were included in the model as fixed effects and block was treated as a random effect. Treatments were analyzed for differences at time point 0, but time point 0 was not included in the model. For all variables, α values <0.05 were considered significant and tendencies were discussed when α values were $0.05 \leq P \leq 0.10$.

Experimental Design and Procedures: Exp. 2

A total of 720 crossbred, calf-fed heifers (initial BW = 281 ± 10 kg) arrived on 3 different dates (240 heifers/date) at the Panhandle Research and Extension Center (Scottsbluff, NE) and were allotted randomly to pens (10 heifers/pen), and pens were subsequently assigned randomly to 1 of 12 treatments of a 3 × 4 factorial arrangement, with 3 implant strategies and 4 slaughter times. Implant strategies studied were (1) a nonimplanted negative control (**NCON**); (2) implanting with Revalor-200 on d 0 and reimplanting with Revalor-200 on d 100 (**PCON**); or (3) implanting with a delayed-release Revalor-XH implant on d 0 (**XH**). Harvest dates were established based on time heifers reached optimal market condition (151 d) and slaughtered at 14-d intervals thereafter (165, 179, and 193 DOF).

On arrival, heifers received a panel tag in the left ear with an individual identification number and a metal tag in the right ear with corresponding identification number. All heifers received a *Clostridium chauvoei*, *specticum*, *novyi*, *sordellii*, *perfringens* Types B, C, and D bacterin-toxoid (Vision 7; Merck Animal Health) for prevention of disease caused by *Clostridium chauvoei* (blackleg), *septicum* (malignant edema), *novyi* (black disease), *sordellii* and *perfringens* Types C&D (enterotoxemia) and 2 mL of Vista Once s.c. (Merck Animal Health) for the prevention of respiratory disease caused by infectious bovine rhinotracheitis virus, bovine viral diarrhea virus (type 2), and respiratory syncytial virus and as an aid in the control of disease caused by bovine viral diarrhea virus (type 1), parainfluenza-3 virus, *Mannheimia haemolytica*, and *Pasteurella multocida.* Upon processing on d 0, heifers also received a 14-mL fenbendazole oral drench (Safe-Guard, Merck Animal Health) for removal and prevention of nematodes. Heifers were housed in pens and limit fed until initiation of the trial.

Heifers were limit fed (2% of BW) the first diet of the step-up ration for 5 d before a 2-d weight collection to minimize variation in gut fill (Watson et al., 2013). On d 0 of the trial, individual BW was recorded, and heifers were assigned randomly to 1 of 12 treatments within 3 initial start date blocks. Based on treatment assigned, heifers were administered their respective implant while in the chute on d 0. Each treatment was represented equally within all 3 start-date blocks, with 2 replications/block for a total of 24 pens (240 heifers)/block. On d 1 of the trial, a pen weight was recorded to serve as the second-day weight collection.

During the trial, bunk space was provided at 54.9 linear cm/heifer and pen space allotted was 6.1 × 4.3 m (26.2 m^2/heifer). The step-up period consisted 3, 4, 7, and 7 d on diets 1, 2, 3, 4, respectively. The common finishing diet fed to all heifers consisted of 58% DRC, 7% corn silage, 4% wheat straw, 25% wet distillers grains, and 6% supplement (DM basis). Heifers were fed once daily and provided ad libitum access to feed and water throughout the trial.

Statistical Analysis: Exp. 2

All data were analyzed using PROC GLIMMIX in SAS (SAS Institute Inc.). Pen was included as the experimental unit, and start block was included as a fixed effect. The model included implant treatments, serial slaughter, and the interaction of implant and serial slaughter as fixed effects. Treatment × linear serial slaughter and treatment × quadratic serial slaughter were analyzed. Due to a significant difference in initial pen weights among treatments, initial pen weight was considered a possible covariate and included in the model. If the covariate was determined to be insignificant ($P > 0.10$) for that variable, initial pen weight was removed from the model as a covariate. Pen initial weight was included as a covariate in the model for final and carcass-adjusted ending BW, HCW, ADG, and

G:F. Orthogonal contrasts were used to test linear and quadratic effects of serial slaughter for heifers. Significance was deemed at an α value of ≤ 0.05, and tendencies were discussed when α values were between 0.05 and 0.10.

RESULTS AND DISCUSSION

Exp. 1

Heifers were evaluated for missing or abscessed implants on d 35 and 105 and, if found, were removed from trial. Two heifers were removed for missing implants on d 35 (1 from each block) and 1 from d 105 (block 1); however, no abscessed implants were observed. Additionally, there was 1 death and 5 removals in block 2 (3 foot rot, 1 navel abscess, and 1 chronic).

Overall, there was no effect ($P = 0.22$) on DMI due to implant treatments over 198-d feeding period (Table 1). This is consistent with observations from Duckett and Owens (1997) based on DMI as a percentage of on-test BW, potentially suggesting that slight changes in DMI with the use of implants is driven by the increase in BW (Reinhardt and Wagner, 2014). Using carcass-adjusted performance, implanted cattle were 19 kg heavier ($P < 0.01$) than CON, but there were no differences ($P \geq 0.87$) between implant treatments. All implanted cattle had 7% greater ADG ($P < 0.01$) compared with CON heifers, which led to implanted heifers being 4% more ($P < 0.01$) efficient. Implant strategies have been well documented to increase ADG by an average of 21% and improve feed efficiency by an average 11%, which is greater than what was observed in the current experiment (Duckett and Owens, 1997; Wileman et al., 2009; Johnson et al., 2013). Kreikemeier and Mader (2004) reported similar results and found that implanted heifers were 11.8 kg heavier and gained 0.108 kg/d more, and heifers receiving a combination implant and melengestrol acetate were more efficient than heifers receiving a single compound implant or no implant. Heifers implanted with XR, E200, or D200 were the most efficient ($P < 0.01$), but E200 and D200 were

Table 1. Performance and carcass characteristics of implanted heifers compared with nonimplanted control heifers fed for an average of 198 d (Exp. 1)

	Implant treatment[1]							Preplanned contrast		
Item	CON	XH	E200	XR	D200	SEM	*F*-test	CON vs. implant	XH vs. D200	XR vs. D200
Live performance										
Initial BW, kg	281	281	280	280	280	8.3	1.00	0.94	0.95	0.99
Live final BW, kg	564	581	577	580	577	12.9	0.26	0.03	0.67	0.69
DMI, kg/d	9.7	10.0	9.9	9.8	9.9	0.26	0.22	0.12	0.28	0.47
Live ADG, kg	1.44[a]	1.52[b]	1.51[b]	1.52[b]	1.50[b]	0.044	0.02	<0.01	0.59	0.55
Live G:F	0.148[a]	0.151[a]	0.152[ab]	0.156[b]	0.153[ab]	0.0015	0.02	0.01	0.54	0.13
Carcass Adj. performance[2]										
Adj. final BW, kg	561	580	580	580	579	12.5	0.09	0.01	0.87	0.90
Adj. ADG, kg	1.42[a]	1.52[b]	1.52[b]	1.52[b]	1.51[b]	0.039	<0.01	<0.01	0.86	0.84
Adj. G:F	0.147[a]	0.151[b]	0.153[bc]	0.156[c]	0.153[bc]	0.0015	<0.01	<0.01	0.29	0.21
Carcass characteristics										
HCW, kg	354	365	365	365	365	7.9	0.09	<0.01	0.88	0.92
DP, %	62.7	63.1	63.3	63.0	63.2	0.12	0.18	0.04	0.81	0.43
LM area, cm^2	79.4[b]	83.9[a]	80.0[b]	82.6[a]	83.2[a]	0.11	<0.01	<0.01	0.62	0.62
Marbling score[3]	569	537	534	543	529	10.6	0.09	<0.01	0.61	0.38
Fat depth, cm	1.70	1.65	1.75	1.68	1.63	0.022	0.58	0.70	0.61	0.44
Calculated YG[4]	3.80[ab]	3.64[a]	3.90[b]	3.69[a]	3.61[a]	0.077	0.04	0.28	0.78	0.47

[a–c]Means within a row without common superscripts differ ($P \leq 0.05$).

[1]Implant treatments included nonimplanted negative control (CON), 200 mg of trenbolone acetate (TBA) + 20 mg of estradiol partially coated pellets (Revalor-XH, Merck Animal Health, De Soto, KS; XH), 200 mg of TBA + 20 mg of estradiol uncoated administered on d 1 (Revalor-200, Merck Animal Health; E200), 200 mg of TBA + 20 mg of estradiol coated implant (Revalor-XR, Merck Animal Health; XR), and 200 mg of TBA + 20 mg of estradiol uncoated administered on d 70 (Revalor-200, Merck Animal Health; D200).

[2]Common DP (63%) used to calculate carcass-adjusted (Adj.) performance.

[3]USDA marbling scores: 400 = small, 500 = modest, 600 = moderate.

[4]Yield grade calculated using the following equation: 2.5 + (0.98425 × 12th-rib fat, cm) + [0.2 × 3.0(KPH, %)] + (0.00837 × HCW, kg) − (0.0496 × LM area, cm^2).

not different from XH ($P > 0.29$), and CON was the least efficient ($P = 0.01$). Comparable performance results were observed when live final performance was evaluated.

Implanted heifers had 11-kg heavier ($P < 0.01$) HCW than CON (Table 1). This response is well documented with an average of 18 to 27 kg of added HCW expected from use of a combination implant (Johnson and Chung, 2007; Johnson et al., 2013; Reinhardt and Wagner, 2014). Although HCW, DP, fat thickness, and marbling scores did not differ ($P \geq 0.38$) among implant treatments, carcasses of CON heifers had reduced ($P = 0.04$) DP and greater ($P < 0.01$) marbling scores than implanted heifers when fed the same DOF. Kreikemeier and Mader (2004) found no differences in USDA marbling score for heifers given estrogenic implants, TBA implants, or no implant; however, carcasses from heifers given an estrogenic–TBA combination implant had lower marbling scores compared with other treatments. Johnson and Chung (2007) reported no effect of implant treatment on fat thickness compared with nonimplanted animals fed the same DOF. Carcasses from heifers in XH, XR, and D200 treatments had larger ($P < 0.01$) LM areas than CON- and E-200-treated heifers, which translated into a lower ($P = 0.04$) calculated YG. Previous researchers have suggested that implanting alters intramuscular fat deposition and composition due to a dilution effect with increasing LM area (Duckett et al., 1999). Duckett and Andrae (2001) found implanting cattle with an estrogenic or combination implant reduced marbling score by 4% but increased LM area by 3 to 4%, respectively.

There was a tendency for a change in the distribution of QG ($P = 0.10$) and YG ($P = 0.07$) between implant treatments and CON (Table 2). Johnson and Chung (2007) noted that the use of growth-promoting technologies shifts nutrient use toward lean carcass tissue rather than adipose tissue, leading to more carcass protein in implanted cattle compared with nonimplanted controls, which may result in lower calculated YG. However, Roeber et al. (2000) reported no differences in final YG because the increase in HCW was offset by the increase in LM area in the calculations used to determine final YG. Roeber et al. (2000) also reported that the percentage of carcasses grading USDA Prime or Choice ranged from 94.4% in nonimplanted control steers to 75% in steers that were implanted with 200 mg of TBA and 28 mg of estradiol benzoate (Synovex Plus, Zoetis). Yet, in the current study, the effect on percentage of heifers grading USDA Choice or Prime was minimal (92.5% CON vs. 91.3% all implant treatments).

During the first 70 d of the feeding period, heifers implanted with XH and E200 had greater ($P = 0.01$) ADG and G:F than other treatments (Table 3). From d 70 to 140, cattle implanted with XR or D200 gained more and were more efficient ($P < 0.01$) than those on the other treatments, which is consistent with the delayed release of XR and the delayed implanting of D200 heifers. From d 140 to 175, all implanted cattle were heavier ($P < 0.01$)

Table 2. Change in QG and YG distribution of implanted and nonimplanted heifers fed for an average of 198 d (Exp. 1)

	Implant treatment[1]					
Item	**CON^{a,xy}**	**XH^{b,x}**	**E200^{b,y}**	**XR^{ab,xy}**	**D200^{b,x}**	***P*-value**
QG, %						0.10
Prime	14.3	6.2	4.2	9.0	6.1	
Upper Choice	56.1	55.7	55.4	54.0	49.0	
Low Choice	22.3	26.8	33.2	28.9	35.9	
Select	7.2	10.3	7.1	8.1	9.0	
Standard	0.0	1.0	0.0	0.0	0.0	
YG, %						0.07
1	1.0	2.0	0.0	2.0	1.0	
2	16.7	16.7	11.6	12.3	16.4	
3	48.6	43.9	37.8	48.4	45.1	
4	28.6	34.3	42.3	34.2	36.4	
5	5.2	3.0	8.3	3.0	1.0	

[a,b]Means within row without common superscripts differ ($P \leq 0.05$) for QG distribution.

[x,y]Means within row without common superscripts differ ($P \leq 0.05$) for YG distribution.

[1]Implant treatments included nonimplanted negative control (CON), 200 mg of trenbolone acetate (TBA) + 20 mg of estradiol partially coated pellets (Revalor-XH, Merck Animal Health, De Soto, KS; XH), 200 mg of TBA + 20 mg of estradiol uncoated administered on d 1 (Revalor-200, Merck Animal Health; E200), 200 mg of TBA + 20 mg of estradiol coated implant (Revalor-XR, Merck Animal Health; XR), and 200 mg of TBA + 20 mg of estradiol uncoated administered on d 70 (Revalor-200, Merck Animal Health; D200).

than CON heifers. Interestingly, from d 140 to the end of the feeding period (d 198), CON heifers had greater ($P \leq 0.05$) ADG and G:F than all implanted heifers.

There were no treatment × time interactions ($P \geq 0.59$) or treatment effects ($P \geq 0.12$) for BUN, NEFA, or IGF-1 circulating concentrations. Serum BUN and IGF-1 concentrations increased ($P < 0.01$) with increasing DOF, from 15.9 to 19.2 mg/dL and from 50.9 to 91.6 ng/mL, respectively (Figure 1). Conversely, blood NEFA concentrations decreased ($P < 0.01$) from 330.1 to 166.9 mEq/L between d 1 and 175 of the feeding trial. Contrary to Exp. 1 results, Smith et al. (2018) reported that serum IGF-1 concentrations increased in implanted steers over a 213-d feeding trial compared with nonimplanted steers. Moreover, Dayton et al. (1997) observed that implanting steers with TBA-containing implants increased circulating IGF-1 concentrations by 40 and 35% after 40 and 115 DOF, respectively, over nonimplanting.

At trial initiation, all treatments were below the detection limit (12.5 pg/mL) of the 17β-TbOH assay, and 17β-TbOH was never detected in serum from CON heifers, regardless of collection time. However, 17β-TbOH concentrations increased markedly after initial implantation or expected release from coated implants (implant treatment × sampling time, $P < 0.01$; Figure 1). After 35 DOF, E200 heifers had greater ($P \leq 0.02$) serum 17β-TbOH concentrations (121.2 pg/mL) than either XH- or XR-treated heifers (53.8 and 23.2 pg/mL, respectively), whereas circulating 17β-TbOH concentrations remained elevated ($P < 0.05$) in E-200 heifers compared with XH-treated heifers (116.5 vs. 45.9 pg/mL) after 70 DOF. Serum levels of 17β-TbOH were greater ($P < 0.05$) in XR-treated heifers than XH- and E200-treated heifers on d 105 (147.2 vs. 55.8 and 57.2 pg/mL, respectively) and d 140 (102.2 vs. 39.9 and 24.0 pg/mL, respectively) of the feeding trial. After 175 DOF, circulating 17β-TbOH levels were undetectable (<12.5 pg/mL) in XH-treated heifers, whereas heifers implanted with the uncoated Revalor-200 on d 70 (D200) had greater ($P < 0.05$) serum 17β-TbOH concentrations than only those implanted once with Revalor-200 at initiation (E200) of the trial (80.1 vs. 21.6 pg/mL). Henricks et al. (1997) reported that heifers who received Revalor-H (140 mg of TBA + 14 mg of estradiol; Merck Animal Health) had elevated serum 17β-TbOH compared with nonimplanted heifers until d 84, when serum 17β-TbOH began to decrease in implanted heifers. Revalor-H is equivalent to the steroidal composition of the coated portion of XH. There were no differences between D200 and XR

Table 3. Interim growth performance of implanted and nonimplanted heifers fed for an average of 198 d (Exp. 1)

	Implant treatment[1]						*P*-value			
Item	CON	XH	E200	XR	D200	SEM	*F*-test	CON vs. implant	XR vs. D200	XH vs. D200
d 0–70										
Initial BW, kg	281	281	280	280	280	3.7	1.00	0.94	0.99	0.95
d-35 BW, kg	322	327	332	321	322	3.6	0.21	0.43	0.83	0.33
d-70 BW, kg	370	379	384	370	370	4.3	0.09	0.23	0.96	0.19
DMI, kg/d	8.8	8.9	8.9	8.6	8.9	0.12	0.34	0.55	0.16	0.68
ADG, kg/d	1.29[a]	1.42[b]	1.50[c]	1.30[a]	1.31[a]	0.029	<0.01	0.01	0.89	0.01
G:F	0.148[a]	0.159[b]	0.169[c]	0.151[a]	0.147[a]	0.0014	<0.01	<0.01	0.28	<0.01
d 70–140										
d-105 BW, kg	426	440	443	436	433	4.8	0.13	0.03	0.65	0.30
d-140 BW, kg	472[a]	494[b]	493[b]	492[b]	491[b]	5.1	0.02	<0.01	0.94	0.71
DMI, kg/d	9.8	10.4	10.3	9.9	10.0	0.03	0.07	0.06	0.77	0.09
ADG, kg/d	1.46[d]	1.65[bc]	1.57[c]	1.74[a]	1.73[ab]	0.032	<0.01	<0.01	0.83	0.08
G:F	0.149[c]	0.160[b]	0.153[bc]	0.176[a]	0.173[a]	0.0009	<0.01	<0.01	0.54	<0.01
d 140–end										
d-175 BW, kg	522[a]	546[b]	543[b]	546[b]	542[b]	4.9	<0.01	<0.01	0.54	0.56
Final BW, kg	563	580	577	580	577	6.0	0.32	0.04	0.70	0.80
DMI, kg/d	10.6	11.0	10.7	10.8	10.9	0.13	0.18	0.06	0.76	0.47
ADG, kg/d	1.57	1.48	1.43	1.51	1.47	0.041	0.23	0.05	0.46	0.82
G:F	0.149[a]	0.134[b]	0.134[b]	0.140[ab]	0.134[b]	0.0018	0.04	<0.01	0.37	0.93

[a–c]Means within a row without common superscripts differ ($P \leq 0.05$).

[1]Implant treatments included nonimplanted negative control (CON), 200 mg of trenbolone acetate (TBA) + 20 mg of estradiol partially coated pellets (Revalor-XH, Merck Animal Health, De Soto, KS; XH), 200 mg of TBA + 20 mg of estradiol uncoated administered on d 1 (Revalor-200, Merck Animal Health; E200), 200 mg of TBA + 20 mg of estradiol coated implant (Revalor-XR, Merck Animal Health; XR), and 200 mg of TBA + 20 mg of estradiol uncoated administered on d 70 (Revalor-200, Merck Animal Health; D200).

($P = 0.28$), and there was no difference between XR and E200 ($P = 0.38$) after 175 DOF.

Exp. 2

There were no ($P \geq 0.23$) interactive effects of implant treatment and serial slaughter for any heifer performance or carcass traits. Dry matter intake did not ($P \geq 0.12$) differ among treatments, but final and DP-adjusted BW ($P < 0.01$) and ADG ($P \leq 0.04$) were greater in implant than NCON heifers (Table 4). In addition, implanted heifers had greater ($P < 0.01$) final and DP-adjusted G:F than nonimplanted heifers, whereas heifers implanted twice with Revalor-200 (PCON) were more efficient ($P \leq 0.07$) than heifers implanted with XH. As previously discussed, the increase in final BW, ADG, and G:F observed in implanted heifers compared with nonimplanted heifers has been well documented; however, the lack of performance differences between PCON and XH may suggest that a more aggressive initial implant is not of added benefit. When comparing the effects of initial implantation of heifers with Revalor-IH (80 mg of TBA/8 mg of E2), Revalor-H (140 mg of TBA/40 mg of E2), or Revalor-200, Hilscher et al. (2016) demonstrated that initial implant had no effect on final BW, DMI, ADG, or G:F, regardless of the common terminal Revalor-200 implant. Similarly, when calf-fed steers received Revalor-IS (80 mg of TBA/16 mg of E2), Revalor-IS and Revalor-200 on d 67, or Revalor-XS (200 mg of TBA/40 mg of E2) as their initial implant, followed by a common terminal Revalor-200 implant on d 133, Oney et al. (2018) observed no differences in performance or carcass traits of steers regardless of initial implant hormone dosage.

Even though implanted (PCON and XH) heifers produced heavier ($P < 0.01$) carcasses than NCON heifers, HCW did not ($P = 0.59$) differ between PCON- and XH-treated heifers (Table 4). Moreover, neither DP, LM area, 12th rib fat thickness, or calculated YG differed between implanted and nonimplanted heifers ($P \geq 0.10$) or between implant treatments ($P \geq 0.48$). Carcasses from NCON heifers had greater ($P < 0.01$) marbling scores than carcasses from implanted (PCON and XH) heifers. Hilscher et al. (2016) reported no differences in HCW, LM area, DP, or 12th-rib fat thickness among implant treatments; however, marbling scores were greater in heifers treated with a mild initial implant (Revalor-IH) compared with those treated with a more aggressive, greater-concentration initial implant (Revalor-H or Revalor-200). Furthermore, Schneider et al. (2007) reported carcass characteristics were not affected by doses of initial implants, and Hutcheson et al. (2002) failed to note differences in growth performance over the entire feeding period, even though marbling scores were reduced by implantation. Use of more aggressive initial implants may not provide growth performance incentives during the finishing phase; thus, it may be more economical to use partially coated, delayed-released implants to achieve comparable growth perfor-

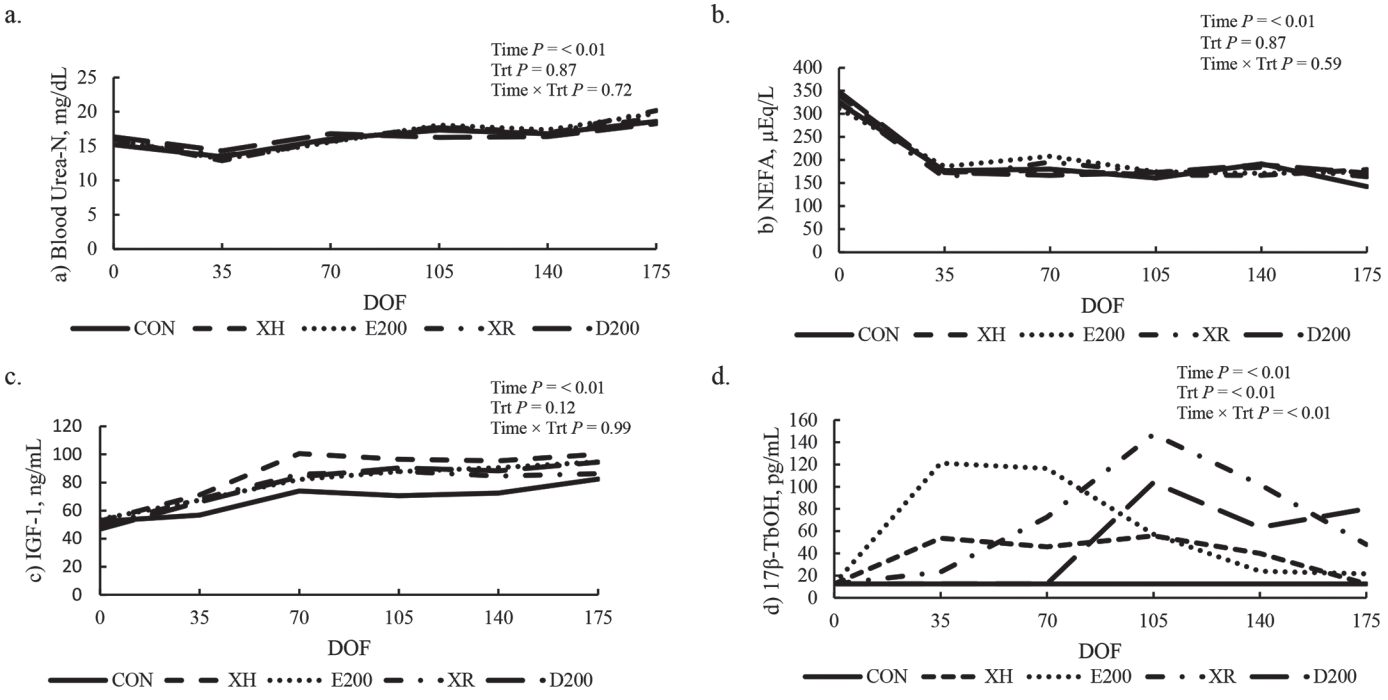

Figure 1. Effects of implant treatment (Trt) on circulating sera metabolite concentrations in finishing heifers (Exp. 1). Treatments included no implant (CON), Revalor-XH [200 mg of trenbolone acetate (TBA) + 20 mg of estradiol (E2), Merck Animal Health, De Soto, KS; partially coated; XH], Revalor-200 on d 1 (200 mg of TBA + 20 mg of E2, Merck Animal Health; uncoated; E200), Revalor-XR (200 mg of TBA + 20 mg of E2, Merck Animal Health; coated; XR), and Revalor-200 on d 70 (Merck Animal Health; D200). Baseline measurements for 17β-trenbolone (17β-TbOH) were less than the lowest detectable level, which is 12.5 pg/mL. DOF = days on feed; NEFA = nonesterified fatty acids.

mance and increased carcass quality as traditional implant protocols without the added stress of reimplanting.

Final and DP-adjusted BW increased linearly ($P < 0.01$) with increasing DOF (Table 5). Although DMI was not ($P \geq 0.38$) affected by DOF, live ADG ($P < 0.01$) and both live and DP-adjusted G:F ($P \leq 0.02$) decreased linearly as DOF increased from 151 to 193 DOF. Vasconcelos et al. (2008) reported a linear increase in final BW, with concomitant linear decreases in ADG and G:F as DOF increased from 136 to 198 d. Dressing percentage was similar ($P = 0.13$) across all serial slaughter dates; however, HCW, 12th-rib fat thickness, calculated YG, and marbling scores increased ($P < 0.01$) linearly with increasing DOF. Rathmann et al. (2012) also reported increased final BW, and decreased ADG and G:F, when heifers were slaughtered between 127 and 167 DOF, and carcass characteristics (e.g., HCW, 12th-rib fat thickness, YG, and marbling scores) increased as heifers were fed for longer periods of time before slaughter.

Live weight gain to carcass weight transfer was calculated by dividing the HCW slope for DOF treatment by the live final BW slope for DOF treatment. When calculated, heifers transferred 89.5% of gain to carcass weight. This means that toward the end of the feeding period, for every kilogram of additional BW, approximately 0.9 kg of HCW was added (Wilken et al., 2015). This is slightly less than what Wilken et al. (2015) concluded in steers, where weight gain transferred to the carcass approached 100% by the end of the feeding period. In a review by Streeter et al. (2012), the author concluded that the carcass transfer in heifers was 86.6% after the first 21-d serial slaughter period but then declined to 65.8% after a 42-d serial slaughter period.

APPLICATIONS

Implanting heifers with aggressive implants or implants with coating technology for delayed and extended release has proven to increase BW, gain and feed efficiency compared with nonimplanted heifers. A more aggressive initial implant had no effect on final BW or ADG. This allows flexibility in effective implant strategies for heifers depending on feedyard personnel availability and management. When heifers were fed to the same DOF, there

Table 4. Main effects of no implant, Revalor-200 on d 1 and reimplanted on d 100, or Revalor-XH on d 1 on heifer growth performance and carcass characteristics (Exp. 2)

	Treatment[1]				*P*-value	
Item	NCON	PCON	XH	SEM	CON vs. implanted	200/200 vs. XH
Live performance						
Final pen BW,[2,3] kg	575	597	595	2.8	<0.01	0.98
DMI, kg/d	11.6	11.7	11.8	0.10	0.12	0.15
Live ADG,[3] kg	1.71	1.84	1.83	0.016	0.04	0.68
Live G:F[3]	0.147	0.158	0.154	0.0013	<0.01	0.05
Carcass-Adj. performance[3,4]						
Adj. final BW, kg	577	598	596	3.0	<0.01	0.58
Adj. ADG, kg	1.72	1.85	1.83	0.02	<0.01	0.55
Adj. G:F	0.148	0.158	0.155	0.001	<0.01	0.07
Carcass characteristics						
HCW,[3] kg	364	377	375	2.0	<0.01	0.59
DP, %	63.2	63.2	63.4	0.002	0.74	0.48
LM area, cm^2	78.1	80.0	78.7	1.9	0.63	0.67
12th-rib backfat thickness, cm	1.85	1.91	1.91	0.01	0.10	0.94
Marbling score[5]	567	533	549	7	<0.01	0.10
Calculated YG[6]	3.98	4.07	4.11	0.11	0.44	0.79

[1]Treatments included no implant (NCON), 200 mg of trenbolone acetate (TBA) + 20 mg of estradiol (Revalor-200, Merck Animal Health, De Soto, KS) on d 1 and a reimplant with Revalor-200 on d 100 (PCON), or 200 mg of TBA + 20 mg of estradiol (Revalor-XH, partially coated; Merck Animal Health; XH).

[2]Final pen BW pencil shrunk 4%.

[3]Initial BW was used as a covariate in the model.

[4]Carcass-adjusted (Adj.) performance calculated as hot carcass weight (HCW) divided by a common DP of 63%.

[5]400 = small, 500 = modest, 600 = moderate.

[6]Yield grade calculated using the following equation: 2.5 + (0.98425 × 12th-rib fat, cm) + (0.2 × 3.0 [KPH, %]) + (0.00837 × HCW, kg) – (0.0496 × LM area, cm^2).

Table 5. Main effects of days on feed (151, 165, 179, or 193 d) on growth performance and carcass characteristics (Exp. 2)

	Days on feed					Contrast		
Item	151	165	179	193	SEM	*F*-test	Linear	Quadratic
Live performance								
Final pen BW,[1,2] kg	567	579	597	613	3.3	<0.01	<0.01	0.46
DMI, kg/d	11.7	11.7	11.8	11.8	0.10	0.72	0.38	0.84
Live ADG,[2] kg	1.89	1.81	1.76	1.72	0.02	<0.01	<0.01	0.20
Live G:F[2]	0.161	0.155	0.15	0.146	0.0021	<0.01	<0.01	0.25
Carcass Adj. performance[2,3]								
Adj. Final BW, kg	558	577	606	623	4.0	<0.01	<0.01	0.78
Adj. ADG, kg	1.83	1.79	1.81	1.77	0.02	0.18	0.10	0.99
Adj. G:F	0.156	0.154	0.154	0.151	0.002	0.1	0.02	0.84
Carcass characteristics								
HCW,[2] kg	351	363	382	392	2.0	<0.01	<0.01	0.79
DP, %	62.3	62.8	63.9	64	0.002	0.49	0.13	0.63
LM area, cm^2	77.4	76.1	82.6	80.6	2.6	0.17	0.09	0.99
12th rib backfat thickness, cm	1.75	1.75	1.96	2.08	0.03	<0.01	<0.01	0.09
Marbling score[4]	538	521	565	574	8	<0.01	<0.01	0.11
Calculated YG[5]	3.83	4	4.04	4.34	0.13	0.05	<0.01	0.60

[1]Final pen BW pencil shrunk 4%.

[2]Initial BW was included as a covariate in the model.

[3]Carcass-adjusted (Adj.) performance calculated by hot carcass weight (HCW) divided by a common DP of 63%.

[4]400 = small, 500 = modest, 600 = moderate.

[5]Yield grade calculated using the following equation: 2.5 + (0.98425 × 12th-rib fat, cm) + (0.2 × 3.0 [KPH, %]) + (0.00837 × HCW, kg) – (0.0496 × LM area, cm^2).

was no effect of implant release rate (coated, uncoated, or delayed) on live performance, but implanted heifers did have a lower USDA marbling score. When feeding heifers for longer DOF, final BW increased, while ADG and G:F decreased, with no regard to implant type.

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