# Performance of finishing beef steers in response to anabolic implant and zilpaterol hydrochloride supplementation[1]

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**ABSTRACT:** Our objectives were to evaluate the dose/payout pattern of trenbolone acetate (TBA) and estradiol-17β ($E_2$) implants and feeding of zilpaterol hydrochloride (ZH) on performance and carcass characteristics of finishing beef steers. A randomized complete block design was used with a 3 × 2 factorial arrangement of treatments. British × Continental steers (n = 168; initial BW = 362 kg) were blocked by BW and allotted randomly to 42 pens (7 pens/treatment; 6 pens/block; 4 steers/pen). The main effects of treatment were implant [no implant (NI); Revalor-S (REV-S; 120 mg of TBA + 24 mg of $E_2$); and Revalor-XS (REV-X; 200 mg of TBA + 40 mg of $E_2$)] and ZH (0 or 8.3 mg/kg of DM for 20 d with a 3-d withdrawal before slaughter). Blocks were split into 2 groups, and block groups were fed for either 153 or 174 d. No implant × ZH interactions were noted for cumulative performance data. Overall, shrunk final BW (567, 606, and 624 kg for NI, REV-S, and REV-X, respectively), ADG (1.25, 1.51, and 1.60 kg), and G:F (0.14, 0.16, and 0.17) increased ($P < 0.05$) as TBA and $E_2$ dose increased. Implanting increased ($P < 0.05$) DMI, but DMI did not differ ($P > 0.10$) between REV-S and REV-X (8.8 for NI vs. 9.4 kg/d for the 2 implants). From d 1 to 112 of the feeding period, implanting increased ($P < 0.05$) ADG and G:F, but REV-S and REV-X did not differ ($P > 0.10$). From d 112 to end, ADG increased by 19% ($P < 0.05$) and G:F was 18% greater ($P < 0.05$) for REV-X vs. REV-S. Carcass-adjusted final BW (29-kg difference), ADG (0.2-kg/d difference), and G:F (0.02 difference) were increased ($P < 0.05$) by ZH, but daily DMI was not affected by feeding ZH. Hot carcass weight was increased ($P < 0.05$) by ZH (19-kg difference) and implant, with REV-X resulting in the greatest response (HCW of 376 for NI vs. 404 and 419 kg for REV-S and REV-X, respectively; $P < 0.05$). An implant × ZH interaction ($P = 0.05$) occurred for dressing percent (DP). Without ZH, implanting increased DP, but DP did not differ ($P > 0.10$) between REV-X and REV-S. With ZH, REV-X increased (1.7%; $P < 0.05$) DP vs. NI and REV-S. Marbling score, 12th-rib fat, and KPH were not affected ($P > 0.10$) by implant or ZH. Overall, treatment increased steer performance and HCW in an additive fashion, suggesting different mechanisms of action for ZH and steroidal implants. In addition, a greater dose of TBA + $E_2$ and extended payout improved steer performance and HCW.

**Key words:** beef steer, estradiol-17β, trenbolone acetate, zilpaterol hydrochloride



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## INTRODUCTION

Recently, 2 new products, Revalor-XS (Intervet/Schering Plough Animal Health, DeSoto, KS) and zilpaterol hydrochloride (**ZH**; Intervet/Schering Plough Animal Health), have been approved for use in finishing cattle. Revalor-XS, a steroidal implant with a dose of 200 mg of trenbolone acetate (**TBA**) and 40 mg of estradiol-17β ($\mathbf{E_2}$), has a unique polymer coating on 6 of 10 implant pellets. This coating results in a gradual, sustained-release rate of TBA and $E_2$ compared with the typical biphasic release rate demonstrated by uncoated cholesterol-based implant pellets and, thereby, eliminates the need to reimplant cattle (FDA, 2007). The 4 uncoated pellets of Revalor-XS immediately show a biphasic release rate after implanting, whereas the coated pellets presumably do not start payout until approximately 80 d after the implant is administered (FDA, 2007).

Protein accretion is increased by TBA + $E_2$ implants, with the greatest response in protein gain occurring

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during the first 40 d after implanting (Hayden et al., 1992; Johnson et al., 1996). Marbling scores may be decreased by steroidal implants. Bruns et al. (2005) noted that intramuscular fat deposition occurs throughout the feeding period and that using a larger dose implant early in the feeding period could reduce the potential for marbling deposition. Results from large-pen experiments suggest that a gradual, sustained release of TBA + $E_2$ such as occurs with Revalor-XS might decrease the negative effects of steroidal implants on marbling (Parr et al., 2009).

Feeding ZH to feedlot cattle increases ADG, G:F, and HCW, while decreasing yield and quality grades (Avendaño-Reyes et al., 2006; Vasconcelos et al., 2008; Elam et al., 2009). Although combining anabolic implants and ZH should improve carcass lean yield, the combination could reduce quality grade (Baxa et al., 2010). Thus, our objective was to determine the effects of source and dose/payout pattern of TBA + $E_2$ with or without ZH on performance and carcass characteristics of finishing beef steers.

## MATERIALS AND METHODS

All procedures involving the use of animals were reviewed and approved by the Texas Tech University Animal Care and Use Committee.

### *Animals and Treatments*

The experiment was conducted at the Texas Tech University Burnett Center located approximately 9.7 km east of New Deal, TX.

British × Continental crossbred steers (n = 199) were received at the Burnett Center in December 2008. Processing occurred approximately 24 h after arrival and included 1) placement of a numbered tag, 2) palpation of ears to detect the presence of any previous implants, 3) measurement of individual BW, 4) vaccination for clostridial and viral diseases (Vista 5 and Vision 7 with Spur; Intervet/Schering Plough Animal Health), and 5) treatment for internal and external parasites with Safe-Guard (Intervet/Schering Plough Animal Health) and Ivomec pour-on (Merial, Duluth, GA). After processing, cattle were fed a 63% concentrate receiving diet. Cattle with extremes in BW, variation in breed type (i.e., not black-hided), or those with evidence of a previous implant were not used in the experiment. Remaining steers (n = 168) were stratified by BW and assigned to 7 blocks based on BW. Steers were then assigned randomly within block to pen and treatment (42 pens total; 7 pens/treatment; 6 pens/block; 4 steers/pen). Steers were gradually adapted from the receiving diet to the final diet using 5 step-up diets (63, 73, 83, 88, and 90% concentrate diets). Steers were consuming the final 90% concentrate diet (Table 1), and intake was stable before the start of the experiment (d 1; 35 d after arrival).

**Table 1.** Ingredient composition and analyzed nutrient content of the final diet (DM basis)

| | Diet | | |
|---|---|---|---|
| Item | Pre-ZH[1] | ZH | Control |
| Ingredient, % | | | |
| Steam-flaked corn | 75.39 | 73.13 | 73.15 |
| Alfalfa hay | 3.93 | 3.93 | 3.93 |
| Cottonseed hulls | 5.95 | 5.92 | 5.92 |
| Cottonseed meal | 4.81 | 4.90 | 4.90 |
| Urea | 0.89 | 0.89 | 0.89 |
| Cane molasses | 3.84 | 3.97 | 3.97 |
| Fat (yellow grease) | 1.96 | 1.99 | 1.99 |
| Supplement[2] | 1.97 | 1.97 | 1.97 |
| Limestone | 1.26 | 1.28 | 1.28 |
| Control premix[3] | — | — | 2.00 |
| ZH premix[3] | — | 2.02 | — |
| Analyzed composition, % | | | |
| DM | 82.60 | 81.66 | 82.31 |
| CP | 12.43 | 12.76 | 12.76 |
| NDF | 15.15 | 15.41 | 15.41 |
| ADF | 7.24 | 7.54 | 7.54 |

[1]Pre-zilpaterol hydrochloride (ZH) = diet fed before ZH supplementation began (d 130 or 151). Then, according to respective treatments, either the control diet was fed for 23 d or the ZH diet was fed for 20 d followed by 3 d of control diet (during ZH withdrawal period).

[2]Supplement supplied (DM basis) 33 mg/kg of Rumensin (Elanco Animal Health, Indianapolis, IN), 11 mg/kg of Tylan (Elanco Animal Health), 2,200 IU/kg of vitamin A, and 17.5 IU/kg of vitamin E.

[3]The control premix contained (DM basis): 98.0% wheat middlings and 2.0% corn oil. The ZH premix contained 0.868% ZH (Intervet/Schering-Plough Animal Health, DeSoto, KS) Type A medicated article, 97.13% wheat middlings, and 2.0% corn oil and supplied ZH at 8.33 mg/kg.

Within the randomized complete block design, treatments were arranged in a 3 × 2 factorial with main effects of implant and ZH supplementation (all products from Intervet/Schering Plough Animal Health). Thus, the 6 treatments were 1) no implant (**NI**) without or 2) with ZH; 3) a single Revalor-S on d 1 (120 mg of TBA and 24 mg of $E_2$; **REV-S**) without or 4) with ZH; and 5) a single Revalor-XS on d 1 (200 mg of TBA and 40 mg of $E_2$; **REV-X**) without or 6) with ZH. Zilpaterol hydrochloride was supplemented to selected treatments for 20 d at a dose of 8.3 mg/kg (DM basis). The ZH was included by means of a wheat middling-based premix (Table 1). A 3-d withdrawal from ZH supplement was initiated before slaughter, during which time the ZH-treated cattle were fed the control diet.

Longissimus muscle biopsy samples (from 1 steer/pen) and blood samples (10 mL collected via venipuncture from 2 steers/pen) were collected periodically throughout the experiment (results not presented in the present manuscript). Because of the logistics of muscle sample collection and the requirement that collections be similar relative to the time of implanting, it was necessary to split the blocks into 2 groups. Steers in the light group (24 pens; 4 blocks) were implanted and started on the experiment 7 d before the heavy group (18 pens; 3 blocks). Steers were treated the same relative to implant until d 131 when the heavy group was supplemented with ZH for 20 d and then slaughtered after a 3-d withdrawal. The light group was not supplemented with ZH until d 152, and slaughter occurred 23 d later.

### *Management*

Individual, unshrunk BW measurements (scale readability ± 0.45 kg) were collected from both groups at the start of the experiment, d 28, before ZH supplementation (d 131 or 152 for the heavy and light groups, respectively), and at the end of the experiment (d 153 or 174, respectively). Intermediate BW (d 56, 84, and 112 for both groups) obtained during the course of the experimental period were collected using a platform scale (scale readability ± 2.27 kg) that was validated with 454 kg of certified weights before each use. For the light group, an additional interim pen BW measurement was collected on d 132. Individual BW also was collected on the 2 steers per pen used for muscle and serum collection during ZH supplementation. Relative to the start of ZH feeding, individual BW data were collected on 2 steers per pen before ZH supplementation, d 11 of ZH, and d 19 of ZH supplementation.

Cattle were fed once daily to provide ad libitum access to feed. Diets were formulated to meet or exceed NRC (1996) nutrient requirements (Table 1). Pen DMI was calculated weekly based on ingredient DM and daily feed deliveries to the pen. Cattle received the same diet until ZH supplementation began. Throughout the experiment, 4 steers were removed from the data set for reasons not related to treatment, and their individual BW contribution to the pen mean was deleted.

At 153 d for the heavy group and 174 d for the light group, steer BW was collected in the morning before shipping the steers approximately 177 km to the Tyson Fresh Meats facility in Amarillo, TX, for collection of carcass data. Carcass measurements included HCW, LM area, estimated percentage of KPH, 12th-rib fat, and marbling score, which were recorded by personnel from Texas Tech University. Final yield grade was calculated from HCW, LM area, 12th-rib fat, and KPH (USDA, 1997).

A 4% shrink was applied to the final BW (final unshrunk BW × 0.96). Carcass-adjusted final BW was calculated as HCW divided by a common dressing percent (**DP**) of 63.5% (base grid value). Carcass gain was calculated cumulatively using a linear equation to predict DP (M. S. Brown, West Texas A&M University, Canyon, TX, personal communication). The predicted DP was applied to the initial BW to determine a predicted initial HCW, which was then subtracted from the actual HCW to calculate cumulative carcass gain. Dress, % = {[0.03 × (4% shrunk initial BW, kg)] + 46.742}.

These BW calculations were used to determine ADG and G:F when BW was shrunk 4%, adjusted based on HCW and a common DP, and used to predict carcass gain and efficiency throughout the feeding period. During ZH supplementation, ADG from d 0 to 11 and from d 12 to 19 were calculated using the BW from the 2 steers/pen used for muscle biopsy and blood collection. Estimated carcass gain during ZH was calculated using a fixed DP of 63.5% applied to the pre-ZH BW and interim ZH BW.

### *Statistical Methods*

Data were analyzed as a randomized complete block design with 3 × 2 factorial arrangement of treatments, with factors of implant treatment and ZH supplementation. Pen was the experimental unit for all analyses. The MIXED procedure (SAS Inst. Inc., Cary, NC) was used to analyze all performance and carcass variables. The model for interim and cumulative steer performance before ZH supplementation (for which there were replicated pens for implant treatments within each block) included the fixed effect of implant, group, and the implant × group interaction. Block within group and block × implant within group were considered random effects. Because of the logistics of muscle sample collection (results not presented in the present manuscript), the blocks were split into 2 groups: the light group (24 pens; 4 blocks) and the heavy group (18 pens; 3 blocks). The effect of group (representing differences in BW and days on feed) was tested to ensure that there was no group × treatment interactions (which would be relevant to results from later analysis of blood and LM biopsy samples). The model for carcass data, interim ZH, and cumulative steer performance included the fixed effect of implant, ZH, implant × ZH, group, and the implant × ZH × group interaction. Block within group was considered a random effect. If implant, ZH, or implant × ZH effects were significant ($P < 0.05$), least squares means were separated using the PDIFF option of SAS. Frequency data were analyzed as binomial proportions using the Glimmix procedure of SAS using the same model as described previously for carcass data with pen as the experimental unit. For the frequency data, the ILINK option of SAS was used to determine treatment distribution means and subsequent SEM. An α level of 0.05 was used to determine significance, with tendencies associated with $P$-values between 0.05 and 0.10.

## RESULTS

### *Steer Performance in Response to Implant Program*

The effect of implant dose and payout pattern on interim and cumulative steer performance before ZH supplementation is shown in Table 2. Implanting increased ($P < 0.05$) BW from d 28 to 152 and increased ($P = 0.01$) ADG and G:F from d 1 to 112. From d 113 to 132, implanting increased ($P = 0.01$) BW, and REV-

**Table 2.** Effect of implant on interim and cumulative steer performance before zilpaterol hydrochloride (ZH) supplementation[1]

| Item | Implant[2] | | | SEM[3] | *P*-value | | |
|---|---|---|---|---|---|---|---|
| | No implant | Revalor-S | Revalor-XS | | Im[4] | Group[5] | Im × group |
| Initial BW, kg | 363 | 360 | 363 | 2.0 | 0.23 | 0.01 | 0.99 |
| 28-d BW, kg | 412[b] | 419[ab] | 422[a] | 3.6 | 0.05 | 0.01 | 0.92 |
| 56-d BW, kg | 458[b] | 477[a] | 479[a] | 4.9 | 0.01 | 0.01 | 0.97 |
| 84-d BW, kg | 496[b] | 526[a] | 530[a] | 6.1 | 0.01 | 0.03 | 0.59 |
| 112-d BW, kg | 534[b] | 570[a] | 579[a] | 7.6 | 0.01 | 0.05 | 0.66 |
| 131-d BW, kg | 559[b] | 596[a] | 612[a] | 8.2 | 0.01 | 0.05 | 0.60 |
| 152-d BW,[6] kg | 569[b] | 611[a] | 624[a] | 10.9 | 0.01 | — | — |
| 1 to 56 d[7] | | | | | | | |
| ADG, kg | 1.71[b] | 2.10[a] | 2.07[a] | 0.072 | 0.01 | 0.04 | 0.95 |
| DMI, kg/d | 9.12 | 9.12 | 9.03 | 0.197 | 0.86 | 0.38 | 0.85 |
| G:F | 0.187[b] | 0.230[a] | 0.230[a] | 0.0057 | 0.01 | 0.01 | 0.98 |
| 1 to 84 d | | | | | | | |
| ADG, kg | 1.59[b] | 1.99[a] | 1.99[a] | 0.060 | 0.01 | 0.02 | 0.45 |
| DMI, kg/d | 9.06 | 9.29 | 9.21 | 0.191 | 0.48 | 0.48 | 0.98 |
| G:F | 0.176[b] | 0.214[a] | 0.216[a] | 0.0045 | 0.01 | 0.01 | 0.26 |
| 85 to 132 d | | | | | | | |
| ADG, kg | 1.31[b] | 1.45[b] | 1.71[a] | 0.075 | 0.01 | 0.22 | 0.74 |
| DMI, kg/d | 8.84[b] | 9.78[a] | 9.97[a] | 0.280 | 0.01 | 0.83 | 0.50 |
| G:F | 0.149[b] | 0.148[b] | 0.172[a] | 0.0061 | 0.01 | 0.18 | 0.89 |
| 1 to 112 d | | | | | | | |
| ADG, kg | 1.53[b] | 1.88[a] | 1.93[a] | 0.058 | 0.01 | 0.02 | 0.55 |
| DMI, kg/d | 8.99 | 9.40 | 9.40 | 0.202 | 0.11 | 0.62 | 0.86 |
| G:F | 0.170[b] | 0.200[a] | 0.206[a] | 0.0045 | 0.01 | 0.01 | 0.65 |
| 113 to 132 d | | | | | | | |
| ADG, kg | 1.32[b] | 1.35[b] | 1.68[a] | 0.106 | 0.01 | 0.28 | 0.71 |
| DMI, kg/d | 8.89[b] | 9.86[a] | 9.98[a] | 0.318 | 0.01 | 0.53 | 0.52 |
| G:F | 0.150[ab] | 0.137[b] | 0.169[a] | 0.0111 | 0.05 | 0.41 | 0.97 |
| 1 to 132 d | | | | | | | |
| ADG, kg | 1.50[b] | 1.80[a] | 1.89[a] | 0.054 | 0.01 | 0.04 | 0.50 |
| DMI, kg/d | 8.98 | 9.47 | 9.49 | 0.215 | 0.07 | 0.60 | 0.81 |
| G:F | 0.167[c] | 0.190[b] | 0.200[a] | 0.0038 | 0.01 | 0.01 | 0.61 |
| 1 to 152 d[5] | | | | | | | |
| ADG, kg | 1.51[b] | 1.81[a] | 1.87[a] | 0.063 | 0.01 | — | — |
| DMI, kg/d | 8.89 | 9.44 | 9.35 | 0.272 | 0.12 | — | — |
| G:F | 0.170[c] | 0.191[b] | 0.200[a] | 0.0032 | 0.01 | — | — |
| 85 to 152 d[5] | | | | | | | |
| ADG, kg | 1.32[b] | 1.43[b] | 1.65[a] | 0.070 | 0.01 | — | — |
| DMI, kg/d | 8.79[b] | 9.75[a] | 9.67[a] | 0.334 | 0.02 | — | — |
| G:F | 0.151[b] | 0.146[b] | 0.171[a] | 0.0048 | 0.01 | — | — |

[a–c]Within a row, means that do not have a common superscript differ, $P < 0.05$.
[1]Unshrunk BW.
[2]Intervet/Schering-Plough Animal Health, De Soto, KS.
[3]SE of the difference between the treatment means, n = 14 pens/treatment mean.
[4]Im = effect of implant.
[5]The blocks were split into 2 groups: the light group (24 pens; 4 blocks) and the heavy group (18 pens; 3 blocks).
[6]Light group only; steers in the light group were on feed for 152 d before ZH supplementation (pens/treatment = 8).
[7]Day 1 represents the day of implanting, which is the start of the experiment (35 d after steers arrived at the feedlot).



X steers had greater BW ($P = 0.08$), ADG ($P = 0.01$), and G:F ($P = 0.02$) than steers implanted with REV-S. Daily DMI was not affected by implant treatment until d 56 to 84 (data not shown) when implanting increased ($P = 0.01$) DMI over the NI treatment. During the beginning of the feeding period, steer performance was similar between REV-X and REV-S. For the last third of the feeding period (d 85 to end), DMI was similar ($P = 0.52$), but ADG and G:F were greater ($P = 0.01$) for REV-X than for REV-S.

### *Steer Performance in Response to Implant and ZH*

The effect of ZH on steer performance is summarized by interim periods in Table 3. No implant × ZH interactions ($P > 0.20$) were detected, but implant × ZH × group interactions were detected for ADG ($P = 0.04$), G:F ($P = 0.01$), and estimated carcass ADG ($P = 0.04$). Main effect means of implant and ZH are presented, and interactive means were separated by group

**Table 3.** Steer performance during zilpaterol hydrochloride (ZH) supplementation[1]

| | Implant | | | | ZH | | | *P*-value | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Item | No implant | Revalor-S | Revalor-XS | SEM[2] | No ZH | ZH | SEM[2] | Im[3] | ZH | Im × ZH |
| BW basis[4] | | | | | | | | | | |
| Pre-ZH BW,[5] kg | 572[c] | 608[b] | 627[a] | 7.0 | 599 | 605 | 5.7 | 0.01 | 0.32 | 0.32 |
| ADG d −23 to −12,[6] kg | 0.91 | 0.91 | 1.23 | 0.236 | 0.81 | 1.23 | 0.193 | 0.31 | 0.04 | 0.51 |
| ADG d −11 to −3,[6] kg | 0.69 | 0.92 | 0.93 | 0.247 | 0.87 | 0.82 | 0.202 | 0.57 | 0.81 | 0.43 |
| ADG d −23 to end,[7,8] kg | | | | | | | | 0.05 | 0.01 | 0.51 |
| Light group[9] | 0.56[b] | 0.83[a] | 0.69[ab] | 0.103 | 0.61 | 0.78 | 0.094 | | | |
| Heavy group | 1.22 | 1.31 | 1.46 | 0.119 | 1.19 | 1.47 | 0.108 | | | |
| DMI, kg/d | 8.02[b] | 8.67[a] | 8.94[a] | 0.294 | 8.70 | 8.39 | 0.240 | 0.01 | 0.21 | 0.84 |
| G:F[7,10] | | | | | | | | 0.21 | 0.01 | 0.29 |
| Light group | 0.075[b] | 0.097[a] | 0.083[ab] | 0.0009 | 0.072 | 0.099 | 0.0076 | | | |
| Heavy group | 0.143 | 0.146 | 0.152 | 0.0108 | 0.131 | 0.163 | 0.0088 | | | |
| Estimated carcass gain[11] | | | | | | | | | | |
| Predicted HCW pre-ZH, kg | 363 | 386 | 398 | 4.6 | 380 | 384 | 3.6 | 0.01 | 0.32 | 0.32 |
| ADG d −23 to −12,[6] kg | 0.58 | 0.58 | 0.78 | 0.150 | 0.52 | 0.78 | 0.123 | 0.33 | 0.05 | 0.47 |
| ADG d −11 to end,[6] kg | 0.47 | 0.86 | 1.07 | 0.248 | 0.28 | 1.33 | 0.203 | 0.07 | 0.01 | 0.54 |
| ADG d −23 to end,[7,12] kg | | | | | | | | 0.01 | 0.01 | 0.21 |
| Light group | 0.36[b] | 0.73[a] | 0.78[a] | 0.103 | 0.36 | 0.89 | 0.084 | | | |
| Heavy group | 0.76[b] | 0.78[b] | 1.02[a] | 0.119 | 0.48 | 1.23 | 0.097 | | | |
| G:F | 0.069[b] | 0.088[a] | 0.102[a] | 0.0088 | 0.047 | 0.125 | 0.0071 | 0.01 | 0.01 | 0.23 |

[a–c]Main effect of implant. Within a row, means that do not have a common superscript differ, $P < 0.05$.

[1]The implant and ZH (8.3 mg/kg, DM basis) were from Intervet/Schering Plough Animal Health, De Soto, KS.

[2]SE of the difference between the treatment means.

[3]Im = effect of implant.

[4]No adjustment. BW gain = (final BW – pre-ZH BW).

[5]BW collected before feeding ZH. Calculations are relative to the end of the experiment, −23 d is the start of ZH (either d 152 or 131 depending on group), and −3 d is the first day of withdrawal before slaughter.

[6]Interim ADG calculated from the 2 steers per pen used for serum and muscle sampling. Pen was the experimental unit.

[7]ADG during ZH calculated from the whole pen. Pen was the experimental unit.

[8]Implant × ZH × group interaction, $P = 0.04$.

[9]The blocks were split into 2 groups: the light group (24 pens; 4 blocks) and the heavy group (18 pens; 3 blocks).

[10]Implant × ZH × group interaction, $P = 0.01$.

[11]Predicted HCW is calculated as pre-ZH BW (d −23 relative to the end of the experiment) or interim ZH (d −11 relative to the end of the experiment) BW × 0.635. HCW gain = actual HCW – (pre-ZH or interim ZH BW × 0.635). The G:F was calculated from the pre-ZH BW calculation.

[12]Implant × ZH × group interaction, $P = 0.04$.

when appropriate. From d −23 to the end of the experiment, ZH supplementation tended ($P < 0.10$) to increase ADG for the light group and increased ADG ($P < 0.05$) for the heavy group compared with no ZH. Supplementing cattle with ZH increased ($P = 0.05$) G:F. On a carcass basis, ADG and G:F were greater ($P < 0.05$) for ZH-supplemented steers from both the light and heavy groups. Based on BW collected from 2 steers per pen, ZH increased ($P = 0.05$) ADG from d 0 to 11 of ZH feeding (d −23 to −12) compared with no ZH. However, from d 12 to 19 of ZH (d −11 to −3), ADG did not differ ($P > 0.10$) between treatments. Carcass gain was increased ($P < 0.05$) by ZH supplementation throughout the ZH feeding period.

Throughout ZH supplementation, the light and heavy groups responded differently to implant treatment with a implant × ZH × group interaction ($P < 0.05$) for ADG and G:F. Nonetheless, DMI was improved ($P = 0.01$) by implanting. For the light group, ADG, on a BW basis, and G:F were greater ($P < 0.05$) for REV-S than for NI, with REV-X being intermediate. For the heavy group, BW ADG tended ($P < 0.10$) to be greater for REV-X than for NI, with REV-S being intermediate, whereas G:F did not differ ($P > 0.10$) among implant treatments. Estimated carcass gain for the light group and G:F were greater ($P < 0.05$) for REV-X and REV-S compared with NI. Live and estimated carcass intermediate ADG did not differ ($P > 0.10$) by implant treatment.

Cumulative effects on performance are summarized as main effect means of implant and ZH (Table 4). Final shrunk BW was 39 kg greater ($P = 0.01$) for REV-S and 57 kg greater ($P = 0.01$) for REV-X than for NI. Revalor-XS increased ($P < 0.05$) shrunk and carcass-adjusted final BW, ADG, and G:F compared with REV-S and NI. The greater TBA + $E_2$ dose and extended payout resulted in an 18-kg increase in final shrunk BW for steers implanted with REV-X than for those implanted with REV-S. On a cumulative basis, REV-S increased ($P = 0.01$) shrunk ADG 17.2% compared with NI, whereas REV-X ($P < 0.05$) increased ADG 21.9% vs. NI and 5.6% vs. REV-S. Cumulative shrunk G:F was increased ($P < 0.05$) 11.8% by REV-S and 16.5% by REV-X compared with NI, and G:F was 5.3% greater ($P = 0.01$) for REV-X than for REV-S. Daily DMI was increased ($P < 0.05$) by implanting,

**Table 4.** Main effect of implant and zilpaterol hydrochloride (ZH) on cumulative steer performance[1]

| Item | Implant | | | | ZH | | | *P*-value | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | No Implant | Revalor-S | Revalor-XS | SEM[2] | No ZH | ZH | SEM[2] | Im[3] | ZH | Im × ZH |
| 4% adjusted[4] | | | | | | | | | | |
| Final BW, kg | 567[c] | 606[b] | 624[a] | 7.7 | 594 | 605 | 6.3 | 0.01 | 0.11 | 0.49 |
| ADG, kg | 1.25[c] | 1.51[b] | 1.60[a] | 0.040 | 1.42 | 1.49 | 0.033 | 0.01 | 0.06 | 0.37 |
| DMI, kg/d | 8.84[b] | 9.36[a] | 9.43[a] | 0.194 | 9.16 | 9.26 | 0.159 | 0.01 | 0.52 | 0.66 |
| G:F | 0.142[c] | 0.161[b] | 0.170[a] | 0.0030 | 0.155 | 0.160 | 0.0025 | 0.01 | 0.05 | 0.62 |
| Carcass adjusted[5] | | | | | | | | | | |
| BW, kg | 592[c] | 636[b] | 659[a] | 8.2 | 614 | 643 | 6.7 | 0.01 | 0.01 | 0.24 |
| ADG, kg | 1.39[c] | 1.67[b] | 1.80[a] | 0.044 | 1.53 | 1.71 | 0.036 | 0.01 | 0.01 | 0.14 |
| G:F | 0.158[c] | 0.179[b] | 0.191[a] | 0.0031 | 0.167 | 0.185 | 0.0025 | 0.01 | 0.01 | 0.12 |
| Carcass gain[6] | | | | | | | | | | |
| Pred. dress, % | 57.18 | 57.10 | 57.19 | 0.059 | 57.15 | 57.16 | 0.048 | 0.21 | 0.76 | 0.74 |
| Pred. HCW, kg | 208 | 205 | 208 | 1.3 | 207 | 207 | 1.1 | 0.21 | 0.75 | 0.73 |
| ADG, kg | 1.07[c] | 1.25[b] | 1.33[a] | 0.028 | 1.16 | 1.28 | 0.023 | 0.01 | 0.01 | 0.15 |
| G:F | 0.122[c] | 0.134[b] | 0.142[a] | 0.0020 | 0.127 | 0.138 | 0.0017 | 0.01 | 0.01 | 0.19 |

[a–c]Main effect of implant. Within a row means that do not have a common superscript differ, $P < 0.05$.
[1]The implant and ZH were from Intervet/Schering Plough Animal Health, De Soto, KS.
[2]SE of the difference between the treatment means except for the distribution data, which are the pooled SE from the ILINK option (SAS Inst. Inc., Cary, NC).
[3]Im = effect of implant.
[4]Calculated as final BW shrunk 4%. Subsequent ADG and G:F calculated from that final BW calculation.
[5]Calculated as HCW divided by 0.635. Subsequent ADG and G:F calculated from that final BW calculation.
[6]Calculated using the equation: predicted (Pred.) dressing percent = [0.03 × (4% shrunk initial BW, kg)] + 46.742. Predicted dress × initial BW = predicted HCW. Subsequent ADG and G:F were calculated from the predicted HCW calculation.

with 5.6 and 6.3% increases for REV-S and REV-X, respectively, compared with NI; however, DMI did not differ ($P = 0.73$) for REV-X and REV-S.

Similar to results for shrunk and carcass-adjusted ADG, calculated carcass ADG and G:F were greater ($P < 0.05$) for REV-X than for REV-S and NI. Supplementing with ZH did not increase shrunk final BW ($P = 0.11$), but tended ($P = 0.06$) to increase ADG and increased G:F ($P = 0.05$). Daily DMI was not affected ($P = 0.52$) by ZH supplementation. Carcass-adjusted final BW, ADG, and G:F were greater ($P = 0.01$) for ZH-supplemented steers. Moreover, on a carcass gain basis, ZH supplementation increased ($P = 0.01$) cumulative ADG and G:F. Implanting with REV-S without supplemental ZH tended to improve ($P < 0.10$) shrunk and carcass-adjusted G:F compared with NI with supplemental ZH (data not shown). Carcass-adjusted ADG and carcass gain were greater ($P < 0.05$) for REV-S without ZH than for NI with ZH. On a shrunk, carcass-adjusted, and carcass-gain basis, ADG, DMI, and G:F did not differ ($P > 0.10$) for REV-S with ZH and REV-X without ZH.

### *Carcass Characteristics*

Steers implanted with REV-X had 19 and 43 kg greater ($P = 0.01$) HCW than REV-S or NI, respectively (Table 5). Supplementation with ZH increased ($P = 0.01$) HCW (Table 5). There was an implant × ZH interaction ($P = 0.05$) detected for DP (Figure 1). This interaction resulted from steers responding differently to REV-S and REV-X when ZH was supplemented. For steers not receiving ZH, DP was greater ($P = 0.05$) for REV-S vs. NI, with REV-X being intermediate. In steers supplemented with ZH, REV-X increased ($P < 0.05$) DP compared with REV-S and NI. An implant × ZH × group interaction ($P = 0.01$) was noted for LM area (Figure 2). When ZH was not supplemented in the heavy group, LM area was greater ($P < 0.05$) for REV-X steers, but LM area did not differ between NI and REV-S steers. When ZH was fed to the heavy group, LM area did not differ ($P = 0.79$) between REV-X and REV-S steers, whereas REV-S tended ($P = 0.08$) to increase LM area compared with NI. In the light group, when ZH was not supplemented, carcasses of REV-X and REV-S steers did not differ ($P = 0.51$) in LM area, but supplementation with ZH increased ($P = 0.01$) LM area for REV-X vs. REV-S. Marbling score and quality grade distribution did not differ ($P > 0.10$) among treatments. In addition, all other carcass characteristics did not differ ($P > 0.10$) among the 3 implant treatments or with ZH supplementation.

## DISCUSSION

A primary goal of this study was to investigate the effect of 2 single implants with different TBA + $E_2$ doses and payout characteristics on performance and carcass traits of finishing steers. For the present study, ADG was increased by REV-S compared with NI steers until d 112; this finding is consistent with Johnson et al. (1996) who reported a decreased REV-S response after 115 d after implant. As expected, REV-X, with its greater TBA + $E_2$ dose/payout increased ADG throughout the feeding period. The response due to REV-S in this study was similar to the 15.6% increase in ADG as

**Table 5.** Main effect of implant and zilpaterol hydrochloride (ZH) on carcass characteristics[1]

| | Implant | | | | Zilpaterol | | | *P*-value | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Item | No Implant | Revalor-S | Revalor-XS | SEM[2] | No ZH | ZH | SEM[2] | Im[3] | ZH | Im × ZH |
| HCW, kg | 376[c] | 404[b] | 419[a] | 5.2 | 390 | 409 | 4.3 | 0.01 | 0.01 | 0.24 |
| 12th-rib fat, cm | 1.49 | 1.60 | 1.59 | 0.089 | 1.55 | 1.57 | 0.074 | 0.39 | 0.88 | 0.23 |
| KPH, % | 2.33 | 2.12 | 2.25 | 0.128 | 2.22 | 2.24 | 0.104 | 0.28 | 0.87 | 0.65 |
| Marbling score[4] | 515 | 488 | 486 | 18.3 | 487 | 507 | 14.9 | 0.24 | 0.19 | 0.74 |
| Quality grade, % | | | | | | | | | | |
| Premium Choice + Prime | 54.76 | 40.15 | 36.90 | 7.20 | 42.08 | 45.59 | 6.11 | 0.17 | 0.67 | 0.86 |
| Choice Minus | 33.54 | 50.88 | 50.02 | 7.15 | 46.29 | 42.97 | 5.90 | 0.16 | 0.68 | 0.26 |
| Select | 8.93 | 8.93 | 10.71 | — | 9.52 | 9.52 | — | — | — | — |
| Standard | 1.79 | 0.0 | 1.79 | — | 1.19 | 1.19 | — | — | — | — |
| Yield grade[5] | 3.03 | 3.10 | 3.00 | 0.115 | 3.10 | 2.98 | 0.094 | 0.68 | 0.18 | 0.45 |
| <2, % | 7.14 | 7.14 | 5.36 | — | 5.95 | 7.14 | — | — | — | — |
| 2 to <3, % | 42.86 | 39.33 | 52.99 | 7.600 | 44.20 | 45.81 | 6.450 | 0.38 | 0.85 | 0.67 |
| 3 to <4, % | 39.91 | 42.21 | 31.48 | 7.197 | 37.83 | 37.66 | 5.723 | 0.51 | 0.98 | 0.50 |
| 4 to <5, % | 8.93 | 10.71 | 7.14 | — | 9.52 | 8.33 | — | — | — | — |
| ≥5, % | 0.0 | 0.0 | 1.79 | — | 1.19 | 0.0 | — | — | — | — |

[a–c]Main effect of implant. Within a row, means that do not have a common superscript differ, $P < 0.05$.
[1]The implant and ZH were from Intervet/Schering Plough Animal Health, De Soto, KS.
[2]SE of the difference between the treatment means except for the distribution data, which are the pooled SE from the ILINK option (SAS Inst. Inc., Cary, NC).
[3]Im = effect of implant.
[4]As determined by Texas Tech University personnel: 400 = small[00]; 500 = modest[00].
[5]Yield grade as calculated by the regression equation (USDA, 1997).

a result of REV-S in steers fed 143 d (Johnson et al., 1996). In addition, the results for REV-X were comparable with those of Guiroy et al. (2002), who summarized multiple implant trials conducted at different locations, 2 of which compared NI, a single REV-S, and Revalor-IS (Intervet/Schering Plough Animal Health) followed by reimplanting with REV-S. Guiroy et al. (2002) reported that reimplanting increased ADG 13.8 and 14.7% in the 2 studies compared with NI, whereas reimplanting increased ADG 4.8% (not significant) and 4.3% ($P < 0.05$) vs. a single REV-S.

Typically, TBA + $E_2$ implants stimulate DMI (Bartle et al., 1992). However, DMI did not increase over nonimplanted control steers until after d 56, a finding that agrees with the results of Johnson et al. (1996) and Bruns et al. (2005), which demonstrated no difference in DMI for the first 40 to 56 d after implanting, respectively. The magnitude of increased DMI in the present study when using REV-X was not as great as the reported value given by FDA (2007). Body weight gain efficiency was increased the first 28 d after implanting in our study, which is consistent with other reports that have shown increased G:F early in the feeding period (Johnson et al., 1996; Bruns et al., 2005). We observed improved G:F with REV-S relative to NI until approximately d 85. This timeline of REV-S response is similar to other data (Bruns et al., 2005), where G:F was increased until d 56, but our timeline of response to REV-S is less than that reported by Johnson et al. (1996), who demonstrated improved G:F until d 115. The magnitude of G:F response in the current study was similar to that observed by Bruns et al. (2005), who noted a 10.5% improvement in G:F with REV-S

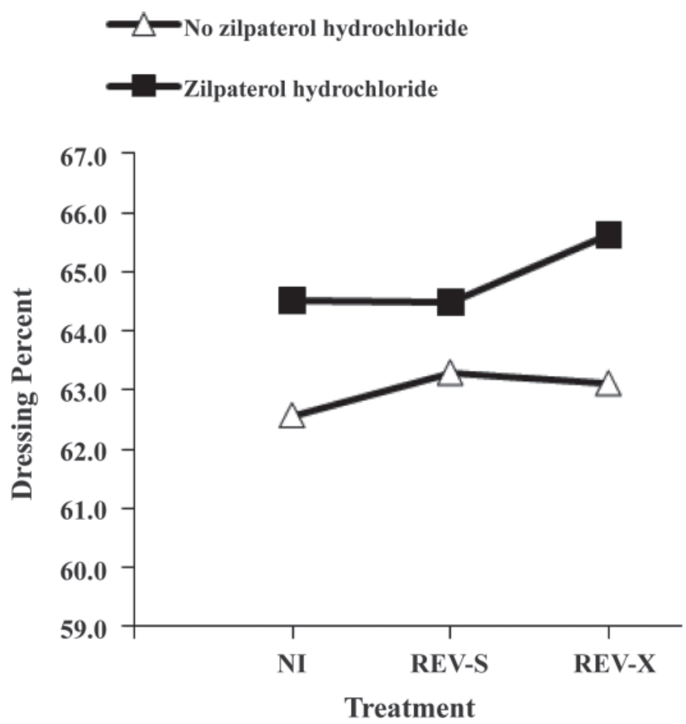


**Figure 1.** Effect of zilpaterol hydrochloride (ZH; 8.3 mg/kg, DM basis; Intervet/Schering Plough Animal Health, De Soto, KS) and implant interaction on dressing percent of beef steers. Implant treatment: NI = no implant, REV-S = Revalor-S, and REV-X = Revalor-XS. Implant × ZH interaction ($P = 0.05$). For steers not receiving ZH, dressing percent was greater ($P < 0.05$) for REV-S (63.30%) than for NI (62.57%) with REV-X (63.12%) being intermediate. For steers supplemented with ZH, REV-X (65.62%) increased ($P < 0.05$) dressing percent compared with REV-S (64.48%) and NI (64.52%) steers. Standard error of the difference between means is 0.353 (n = 7 pens/treatment mean).

vs. NI steers. The response we observed with REV-X is greater than noted by Guiroy et al. (2002) who found that G:F was increased by 10.1% (not significant) and 9.4% ($P < 0.05$) for steers implanted with Revalor-IS followed by REV-S compared with NI steers. However, G:F did not differ between implant strategies.

Effects of combination TBA + $E_2$ implant on carcass characteristics have been researched and reviewed by others (Bartle et al., 1992; Johnson et al., 1996; Montgomery et al., 2001). Typically, a single TBA + $E_2$ implant will increase HCW compared with NI steers, and reimplanting with a combination implant results in the greatest HCW response (Montgomery et al., 2001). Similar to the results in the present study, previous research has reported that TBA + $E_2$ implants often have no effect on 12th-rib fat thickness and can result in a similar or decreased percentage of KPH (Herschler et al., 1995; Johnson et al., 1996; Bruns et al., 2005). Carcass yield grade in the present study was not responsive to implants; likewise, Bartle et al. (1992) and Johnson et al. (1996) reported similar yield grades for NI or REV-S implanted steers. In contrast, Samber et al. (1996) reported increased carcass yield grades vs. NI steers by using 2 REV-S implants during the feeding period. However, Roeber et al. (2000) evaluated the effect of estrogenic or TBA + $E_2$ implants used once or multiple times throughout the feeding period and found that for the yield grade equation, an increase in yield grade resulting from greater HCW was offset by an increase in LM area resulting in no overall effect of implant on calculated yield grade. This phenomenon may explain the lack of yield grade response to ZH observed in the current study.

The effect of different implant strategies on marbling was investigated by Duckett and Andrae (2001), who found that a single TBA + $E_2$ implant decreased marbling score by approximately 4% and reimplanting cattle decreased marbling by 6 to 11% relative to NI steers. Recently, Baxa et al. (2010) reported a 4.6% decrease in marbling score for steers receiving a Component TE-IS (80 mg of TBA and 16 mg of $E_2$; Elanco Animal Health, Greenfield, IN) implant followed by REV-S compared with steers that only received a single Component TE-IS. Similar to the results of the present study, Johnson et al. (1996) reported no difference in marbling scores between NI and REV-S-implanted steers. Bruns et al. (2005) found that delaying implanting with REV-S until d 57 of the feeding period resulted in similar marbling scores, whereas implanting at d 0 decreased marbling relative to NI steers. For this study, cattle were adapted to pen, on the final diet, and DMI was stable before implanting. Management of caloric intake and timing of implanting may help explain the absence of decreased marbling scores even with greater TBA + $E_2$ dose. The gradual sustained release of TBA + $E_2$ associated with REV-X might control decreases in marbling typically associated with multiple TBA + $E_2$ implants. In addition, anabolic implants increase cattle mature size, thereby increasing the required final BW at slaughter for body composition to be similar to NI cattle. Preston et al. (1990) noted that implanted steers required a 39.5-kg heavier BW at slaughter vs. NI steers to reach a similar degree of marbling. Likewise, Guiroy et al. (2002) found that a 42-kg increase in shrunk final BW was needed for steers implanted with Revalor-IS and reimplanted with REV-S to reach a similar final body composition to NI steers. In the present study, compared with NI, REV-S and REV-X steers had a 39- and 57-kg heavier shrunk final BW than NI steers, respectively. Thus, the response we observed for marbling scores may have been a result of management of DMI and implant timing, delayed TBA + $E_2$ payout technologies, and a sufficient increase in final BW for implanted steers.

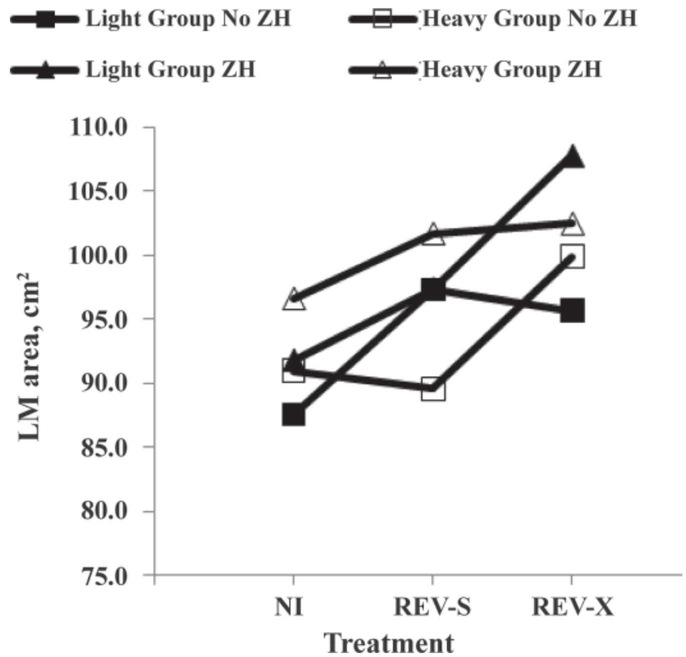


**Figure 2.** Effect of zilpaterol hydrochloride (ZH; 8.3 mg/kg, DM basis; Intervet/Schering Plough Animal Health, De Soto, KS) and implant × group interaction on LM area of beef steers. Implant treatment: NI = no implant; REV-S = Revalor-S; and REV-X = Revalor-XS. The blocks were split into 2 groups: light (24 pens; 4 blocks) and heavy (18 pens; 3 blocks). Steers in the light group were implanted 7 d before the heavy group, but steers were treated the same relative to implant until d 131 when the heavy group was fed ZH; the light group was not fed ZH until d 152. The implant × ZH × group interaction was $P = 0.0038$. Among the heavy group, REV-X-implanted steers had a greater ($P < 0.05$) LM area compared with NI regardless of ZH. When ZH was not supplemented, LM area was greater ($P < 0.05$) for REV-X steers compared with REV-S, but LM area was similar between NI and REV-S. When ZH was supplemented, LM area did not differ ($P > 0.10$) for REV-X and REV-S steers, whereas REV-S tended ($P = 0.08$) to increase LM area compared with NI. In the light group, LM area was greater ($P < 0.05$) for REV-X and REV-S steers compared with NI regardless of ZH. When ZH was not supplemented, REV-X and REV-S had similar ($P > 0.10$) LM area, but supplementation with ZH increased ($P < 0.05$) LM area for REV-X compared with REV-S.

A secondary goal of this study was to determine the effect of ZH when combined with different doses/release rates of TBA + $E_2$ on steer performance and carcass traits (in particular marbling score and quality grade). The results we observed in shrunk final BW for steers fed ZH are consistent with results from small pen studies conducted by Vasconcelos et al. (2008) and Holland et al. (2010). In agreement with Vasconcelos et al. (2008) and Elam et al. (2009), we observed increased shrunk and calculated carcass ADG in ZH fed steers during the supplementation period. The implant × ZH × group interaction detected for ADG and G:F during ZH feeding seemed to be a result of different responses among groups to implants rather than group differences in response to feeding ZH. The light group was on feed for a longer period, and average daily temperatures were greater during ZH supplementation for the light group. Perhaps these differences might explain ADG variation by group. Daily gains were less for the light than the heavy group, but the magnitude of response to ZH was similar between the groups (22 and 19% increase in ADG with ZH in the light and heavy groups, respectively). It is interesting to note the differences in live and calculated carcass ADG throughout ZH supplementation. For the first 11 d of ZH, ADG was increased 34% and carcass gain was increased 33% by ZH. For the rest of the ZH period, ADG did not differ between control and ZH-supplemented steers, but carcass gain was increased 78% by ZH. This may indicate that on a BW basis ZH was more effective at the beginning of the supplementation period, but carcass gain was greater toward the end of ZH supplementation.

In the present study, DMI was not influenced by ZH, which agrees with the results of Vasconcelos et al. (2008) and Elam et al. (2009). In contrast, Holland et al. (2010) noted that feeding ZH decreased DMI during supplementation, and Montgomery et al. (2009a) observed a tendency for decreased DMI with ZH. Regardless of effects on DMI, feeding ZH improved G:F, a result that is supported by previous research (Vasconcelos et al., 2008; Elam et al., 2009; Montgomery et al., 2009a).

Feeding ZH has consistently increased HCW, DP, and LM area in large- and small-pen experiments conducted in the United States (Vasconcelos et al., 2008; Elam et al., 2009; Montgomery et al., 2009a,b). In the current study, the HCW response was consistent with the findings of a study conducted at the Burnett Center by Vasconcelos et al. (2008), who reported a 17.2-kg increase in HCW by feeding ZH. However, our response was greater than that noted in other studies (12.7-, 13.0-, and 11.0-kg increase for Elam et al., 2009; Montgomery et al., 2009a; and Holland et al., 2010, respectively). Feeding ZH increased shrunk final BW by 11 kg (not significant) and HCW by 19 kg in our study. Others have reported greater increases in HCW vs. BW (Montgomery et al., 2009a,b; Holland et al., 2010). Several theories have been proposed to explain this phenomenon, such as repartitioning of body mass from noncarcass components to carcass tissues or differences in tissue deposition rates for carcass and noncarcass components (Montgomery et al., 2009b; Holland et al., 2010). Data from Holland et al. (2010) suggest that increased nutrient utilization efficiency of the carcass tissues accounts for increases in muscle mass rather than nutrient repartitioning from noncarcass to carcass components.

It has been well established that feeding ZH improves DP by 1.8 to 2.6% compared with controls (Vasconcelos et al., 2008; Elam et al., 2009; Montgomery et al., 2009a; Holland et al., 2010). Dressing percent was increased by ZH in our study, but an unexpected interaction between implant and ZH also was detected. Review of literature reveals that the response in DP as a result of REV-S (or a similar TBA and $E_2$ dose) is inconsistent. Bruns et al. (2005) reported a 0.94% increase in DP with REV-S, but others reported similar DP for steers implanted with a single combination implant or NI (Bartle et al., 1992; Johnson et al., 1996). Baxa et al. (2010) reported an increased DP in steers fed ZH for 30 d and implanted with REV-S without implant × ZH interactions in DP.

The significant implant × ZH × group interaction noted for LM area in the present study resulted from the failure of REV-S to increase LM area over NI for the heavy group and the large increase in LM area for REV-X when steers in the light group were fed ZH. Steers implanted with REV-S and fed for 115 d showed a 6.5% increase in LM area compared with steers that were NI (Johnson et al., 1996). Bruns et al. (2005) reported a 6.1% increase in LM area with REV-S compared with NI steers. Others have reported no difference in LM area of steers that were NI or implanted once with 140 mg of TBA + 28 mg of $E_2$ (Perry et al., 1991; Herschler et al., 1995). Feeding ZH for 20 d at a dose of 8.3 mg/kg of DM has increased LM area from 5.7 to 10.2% vs. controls (Vasconcelos et al., 2008; Elam et al., 2009; Montgomery et al., 2009a). Correspondingly, we observed increased LM area with ZH, although not for REV-S-implanted steers in the light group or REV-X-implanted steers in the heavy group.

Feeding ZH for 20 d at 8.3 mg/kg of DM decreased 12th-rib fat and KPH fat (Vasconcelos et al., 2008; Elam et al., 2009). Similar to our results, both Montgomery et al. (2009a) and Holland et al. (2010) reported no effect of ZH on 12th-rib fat or KPH. Feeding ZH consistently decreased calculated yield grades from 7.6 to 14.1% (Vasconcelos et al., 2008; Elam et al., 2009; Montgomery et al., 2009a,b). In contrast, we observed no effect of ZH on yield grade. Given that HCW and LM area were the only carcass variables affected by ZH, the phenomenon described by Roeber et al. (2000) of greater HCW offset by increased LM could explain the lack of ZH effect on yield grade in the current experiment.

Marbling score and quality grade distributions were not significantly affected by ZH in our study. Previous research established that feeding ZH for 20 d at 8.3 mg/kg of DM decreased marbling score 3.4 to 7.4% (Vasconcelos et al., 2008; Elam et al., 2009; Montgomery et al., 2009a). The lack of a ZH effect on marbling score and quality grade distribution could be a function of several variables. First, in the current study, ZH feeding began at a heavier BW (average 602 kg) than was the case in several other studies. In the United States, 4 experiments have been published that fed ZH at 8.3 mg/kg of DM for 20 d, and the BW before feeding ZH ranged from approximately 535 to 566 kg (Vasconcelos et al., 2008; Montgomery et al., 2009a; Holland et al., 2010); BW was heavier (approximately 600 kg) in the work reported by Elam et al. (2009) from pooled analysis of multiple studies. Although a direct comparison across different ZH trials conducted in the United States is not possible, marbling score was decreased the least (3.4%) when BW before the start of ZH feeding was the greatest. Consequently, for the present study, steers may have been fatter before feeding ZH, resulting in a lesser effect of ZH on carcass fatness and marbling. In addition, steers used in the present study had exceptionally high overall quality grades, with 89.3% of the NI without ZH steers grading USDA Choice or greater. Perhaps the effect of ZH on marbling is more dramatic in steers with less genetic potential for marbling than those used in the present study.

Overall, the results of our study suggested a general trend toward additive effects between implants and ZH. Baxa et al. (2010) also noted an additive response with improved performance when REV-S (all steers were implanted with Component TE-IS, and then were NI or received REV-S 91 d before slaughter) and ZH (fed for 30 d at 0 or 8.3 mg/kg of DM) were combined. In the present study, when calculated on a carcass basis, we observed the greatest numerical increase in ADG and G:F when the greater TBA + $E_2$ dose and extended payout of REV-X was combined with ZH; however, there were no significant interactions. Likewise, DP and HCW also were greatest with increased TBA + $E_2$ dose and payout combined with ZH. Steer performance and carcass traits and the associated lack of implant × ZH interactions suggest different modes of action for steroidal implants and ZH. It is interesting to note the similarity in steer performance between REV-S with ZH and REV-X without ZH (data not shown). Our results suggest that performance would be similar in steers receiving a larger TBA + $E_2$ dose implant compared with steers receiving a smaller dose implant and supplemented with ZH. On a carcass-calculated basis, these growth-promoting strategies seemed to separate somewhat numerically but were statistically not different. Carcass weights were similar, but DP was improved by REV-S with ZH when compared with REV-X without ZH. Similarities in performance but differences in carcass characteristics with various growth-promoting technologies should be taken into account when marketing cattle.

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