Effects of Synovex One Grass, Revalor-G, or Encore implants on performance of steers grazing for up to 200 days

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ABSTRACT

Growth rates by cattle ($n = 986$) grazing for 200 d and treated with Synovex One Grass (SOG; 150 mg of trenbolone acetate, 21 mg of estradiol benzoate), Revalor-G (REVG; 40 mg of trenbolone acetate, 8 mg of estradiol), or Encore (ENC; 43.9 mg of estradiol) were measured under field use conditions in a randomized complete block design. Blocks were defined by study start dates ($n = 3$). Crossbred beef cattle, which included steers ($n = 669$) and bulls castrated upon arrival ($n = 317$), were stratified by sex and pretreatment BW within start date and assigned to treatments within strata ($n = 328$ to 330 per treatment, initial BW = 191 ± 2.3 kg). Implants were given on d 0 after BW was measured. Blocks were subdivided into pasture management groups with equal numbers from each treatment on each pasture, and animal was the experimental unit. Cattle grazed pastures supplemented with 26% CP concentrate and bermudagrass hay during periods of limited forage. Cattle BW were also measured on d 70 and 200; implant status (present or absent) was documented on d 70. Average BW of SOG cattle (391.2 kg) was greater ($P < 0.05$) on d 200 than REVG (380.7 kg) or ENC (381.4 kg). Between d 0 and 200, ADG by SOG cattle was 1.00 kg/d, which was greater ($P < 0.05$) than REVG (0.95 kg/d) or ENC (0.95 kg/d). Economics were assessed based on cattle purchase and sale prices, implant costs, and morbidity; cattle treated with SOG returned \$24.35 more than REVG and \$26.77 more than ENC ($P < 0.05$). Over 200 d, grazing cattle implanted with SOG gained more than REVG or ENC, which increased returns.

Key words: cattle, stocker, implant, growth rate, average daily gain

INTRODUCTION

Growth-promoting implants are widely considered among the most effective technologies available to beef producers to reduce cost of production because they increase rate of BW gain and improve the efficiency by which dietary nutrients are converted to body mass (Kuhl, 1997; Duckett and Andrae, 2001; Selk et al., 2006). There are many growth-promoting implant products approved for use in cattle, which typically contain at least an estrogenic or androgenic compound, but most contain both. Most implants approved for use in stocker cattle release growth-promoting active ingredients for periods of 80 to 100 d (Selk et al., 2006). This implies that cattle treated with such products do not benefit from the growth-promoting effects of implants beyond 120 d unless they are reimplanted (Selk et al., 2006). Revalor-G (REVG; Merck, Madison, NJ) is a combination product approved for use in pastured steers and heifers. The REVG product label does not specify duration of activity but rather indicates that the product contains 8 mg of estradiol and 40 mg of trenbolone acetate in a slow-release delivery system. There are, however, products designed and labeled to deliver anabolic agents for extended durations, thereby reducing labor costs and production losses associated with disruption of cattle performance to gather and reimplant animals in the middle of a grazing season. Estrogen-only products (Ferguson et al., 1988) are available for use in grazing steers, which are effective for 200 d (Compudose; Elanco, Indianapolis, IN) or 400 d [Encore (ENC); 43.9 mg of estradiol; Elanco]. Recently, Synovex One Grass (SOG; Zoetis, Parsippany, NJ), a combination product containing 21 mg of estradiol benzoate and 150 mg of trenbolone acetate per dose, was shown to be effective for growth promotion in pastured steers and heifers for up to 200 d (Cleale et al., 2015).

To date, little comparative data have been published that document growth performance of cattle implanted with products commonly administered to pastured cattle. The purpose of this study was to compare growth performance by steers implanted with SOG, REVG, or ENC over a 200-d grazing period.

The authors declare no conflict of interest.

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MATERIALS AND METHODS

The study was conducted under the direction of a licensed veterinarian with beef cattle at a commercial stocker enterprise that was operated under routine management practices in accordance with the Animal Welfare Act (7 U.S.C. 54) and FASS (2010).

Animal Acquisition and Processing

Beef cattle ($n = 1086$) with British or Continental breeding or both (BW = 114 to 250 kg) were acquired in 12 lots between January 5, 2016, and January 28, 2016, and transported less than approximately 235 km to the study site, located in Copan, Oklahoma. After arrival and until d-0 processing, cattle were maintained in paddocks. At least 14 d were allowed for cattle to become acclimated to the study facility before treatment administration. Intact bulls ($n = 317$) were banded at arrival processing, and samples were collected from all cattle to identify those persistently infected with bovine viral diarrhea; bovine viral diarrhea-positive animals were excluded from the study. All animals received Dectomax Injection (Zoetis) at a dose based on average purchase BW and were vaccinated with Titanium 5 (Elanco) and Cavalry 9 (Merck). Cattle were identified with duplicate ear tags that did not disclose experimental treatments. As animals were processed, weighed, and given experimental treatments on d 0, each steer also received Titanium 3 (Elanco), Vision 7 (Merck), and Valbazen (18 mL/animal, Zoetis). In addition, as animals were weighed on d 70, they received treatment with LongRange

dewormer (5 mL/animal; Merck) and a Tolfenpro Insecticidal ear tag (Bayer, Shawnee Mission, KS).

Study Design and Animal Management

Animal ($n = 986$ enrolled) was the experimental unit, and the study used a randomized complete block design. Each block consisted of approximately equal numbers of animals from each treatment that began and ended the study on the same date. The primary blocking criterion was calendar date on d 0, and animals were enrolled into the study on 3 different calendar dates (Table 1). Enrollment to block 1 on January 25 included 323 steers that averaged 193 kg ($n = 110$ to SOG, 108 to REVG, and 105 to ENC). Enrollment to block 2 on February 1 included 327 steers that averaged 191 kg ($n = 110$ to SOG, 110 to REVG, and 107 to ENC). Finally, enrollment to block 3 on February 8 included 336 steers that averaged 191 kg ($n = 110$ to SOG, 110 to REVG, and 116 to ENC). Steers that completed the study grazed 200 d.

During processing on d 0, animals purchased as bulls that were banded at the time of arrival (at least 14 d before experimental treatment administration) were examined to confirm testes were not present. Animals within blocks were stratified based on individual d-0 BW and sex at arrival (steers or banded bulls) and then assigned randomly to treatments within strata. Animals within blocks were further subdivided into management cohorts consisting of approximately equal numbers of animals from each of the 3 treatments that remained together throughout the

Table 1. Summary of animal enrollment

Item	Treatment ¹		
	SOG	REVG	ENC
Block 1			
No. of cattle enrolled	110	108	105
No. of steers, banded bulls	85, 25	83, 25	86, 19
Weight d 0, kg	193.6	193.2	192.0
Treatment date	Jan. 25, 2016	Jan. 25, 2016	Jan. 25, 2016
Completion date	Aug. 12, 2016	Aug. 12, 2016	Aug. 12, 2016
Block 2			
No. of cattle enrolled	110	110	107
No. of steers, banded bulls	69, 41	67, 43	66, 41
Weight d 0, kg	190.9	189.9	192.1
Treatment date	Feb. 1, 2016	Feb. 1, 2016	Feb. 1, 2016
Completion date	Aug. 19, 2016	Aug. 19, 2016	Aug. 19, 2016
Block 3			
No. of cattle enrolled	110	110	116
No. of steers, banded bulls	70, 40	69, 41	74, 42
Weight d 0, kg	192.5	189.6	190.0
Treatment date	Feb. 8, 2016	Feb. 8, 2016	Feb. 8, 2016
Completion date	Aug. 26, 2016	Aug. 26, 2016	Aug. 26, 2016

¹SOG = Synovex One Grass (Zoetis, Parsippany, NJ); REVG = Revalor-G (Merck, Madison, NJ); ENC = Encore (Elanco, Indianapolis, IN).

study. Two pasture management groups were created from block 1 cattle ($n = 163$ for group 1; $n = 160$ for group 2), 2 pasture management groups from block 2 ($n = 162$ for group 1; $n = 165$ for group 2), and 3 pasture management groups for block 3 ($n = 107$ for group 1; $n = 119$ for group 2; $n = 110$ for group 3).

On d 0, BW (mean = 191 ± 2.3 kg) were recorded and implants were administered using product-specific devices for each implant. Persons employed by the study site with appropriate training and experience administered implants according to product labels and instructions. Implants were placed subcutaneously in the middle one-third of the back of one ear per each animal and at least 2.5 cm from ear tags. Evidence of preexisting implants was not detected during treatment administration on d 0. Preparation of implant sites before treatment was as described by Selk et al. (2006) and Cleale et al. (2015). Cattle with clean and dry ears were implanted without cleaning. Cattle with ears that were wet or covered with manure or mud were scrubbed with a brush soaked in disinfectant solution (Nolvasan; Zoetis) before implanting using a “scrape, brush, and disinfect” technique on the ear. Implant device stylets were cleaned in disinfectant solution after each animal was treated. Following implant administration, implant sites were lightly palpated to confirm administration was successful.

Over approximately the first 70 d following treatment (February 25, 2016, to April 15, 2016), cattle in all management groups were housed in small pastures (traps) and grazed dormant winter grass supplemented with free-choice bermudagrass (*Cynodon dactylon*) hay and up to 1.32 kg/animal per day of 26% CP concentrate (Table 2); additional mineral and salt supplement was not offered during the first 60 d. After cattle were weighed on d 70, those assigned to block 1 and block 2 grazed native pastures with approximate botanical composition of 25% big bluestem (*Andropogon gerardii*), 25% indiangrass (*Sorghastrum nutans*), 25% switchgrass (*Panicum virgatum*), 10% fescue (*Festuca arundinacea*), and 15% other (weeds and so on) at a stocking density of approximately 1.01 ha/animal through completion of the study on d 200. After d 70, cattle in block 3 grazed pastures containing 70% bermudagrass (*Cynodon dactylon*), 25% fescue (*Festuca arundinacea*), and 5% other (weeds and so on) at a stocking density of approximately 0.49 ha/animal through completion of the study. Water was available ad libitum from bodies of water (e.g., ponds). After April 15, 2016, 26% CP concentrates were offered at feeding levels dependent on visible assessment of pasture forage maturity. In addition, from d 60 to study completion, mineral-salt supplement was offered. Records were maintained of the pasture on which each animal was located throughout the study. A record of dates and quantities of supplemental feeds provided to each pasture was maintained, but unconsumed quantities of hay and supplement were not measured. These data are summarized across pasture management groups in Table 3.

Data Collected

The study centered on measurement of full BW and health of steers so that ADG could be computed. Scales used to weigh cattle were inspected and calibrated within 12 mo from d 0 of the study. Individual animal BW were obtained before treatment on d 0, then on d 70, and at completion of the study on d 200, and computations of ADG were based on full BW. Cattle were observed daily for potential adverse reactions and health abnormalities and to ensure adequate pasture, supplement, and water availability. Steers that exhibited clinical signs consistent with bovine respiratory disease (BRD) were restrained and body temperatures were measured; those that were febrile (body temperature $\geq 40^\circ\text{C}$) were treated with tulathromycin at the labeled dose or florfenicol at the labeled dose. Animals with clinical signs of BRD but with body temperature $< 40^\circ\text{C}$ did not receive antibiotic treatment. Products and doses administered were documented, and cattle treated 3 or more times for BRD were considered to have chronic respiratory disease. Animals with signs of foot rot were treated with ceftiofur hydrochloride, and pinkeye was treated with ceftiofur hydrochloride or oxytetracycline. A component of daily observations was to document suspected adverse drug events potentially related to experimental treatments, but none were observed. Treatment and return to pasture was permitted for routine BRD, pinkeye, foot rot, or other illnesses. When animal welfare was compromised, steers were removed from study, and the cause of animal removal was documented. Once removed, steers were not returned to pastures with

Table 2. Guaranteed analysis of commercial 26% CP concentrate supplement¹

Item	Value
Ingredient composition, 90% DM basis, %	
Cottonseed meal	46.32
Wheat middlings	36.56
Corn gluten 16% CP	4.87
Limestone 38% Ca	2.44
Molasses	7.31
Mineral mix	2.44
Rumensin 90	0.06
Formulated nutrient composition, DM basis	
CP, %	26.0
NE _m , Mcal/kg	1.52
NE _g , Mcal/kg	0.97
Crude fat, %	2.54
NDF, %	27.12
Calcium, %	1.68
Phosphorus, %	1.25
Potassium, %	0.5

¹Mid America Feeds Inc. (Talala, OK). Feeding instructions: 0.45 to 1.8 kg/head per day with good forage and water.

study animals. One moribund animal was euthanized in accordance with AVMA (2013) because of a broken leg.

Implant sites were observed when animals were weighed on d 70, and observations were documented. Implanted ears on each animal were palpated to document presence or absence of the implant (1 = present, 0 = absent) and whether local implant site reactions were evident (e.g., evidence of abscess); data were summarized as previously described (Cleale et al., 2015).

Statistical Analysis

Animal was the experimental unit in analysis of all variables of interest. Based on BW measured on d 0, 70, and 200, BW gains and ADG were computed for the intervals from d 0 to 70, d 70 to 200, and d 0 to 200. Primary study conclusions were based on data from all enrolled animals that completed the study, regardless of whether the implant was lost. However, analysis of BW gain data was also conducted for only animals that did or did not lose

implants on or before d 70. Purchase prices for stocker cattle, prices received for feeder cattle exiting the study, implant costs, and estimated morbidity costs associated with labor and products purchased to treat animals were used to perform a partial budget analysis of economic implications resulting from implant treatment selections.

All study animals were steers on d 0. However, approximately 32% were not castrated until at least 14 d before d 0. Allocation and randomization of animals to treatments accounted for whether animals were steers or bulls at arrival, and approximately equal numbers of steers that arrived as bulls were assigned to each experimental treatment (Table 1). Normally distributed response criteria were analyzed by PROC MIXED procedures of SAS (SAS Institute Inc., Cary, NC) to evaluate the fixed effects of treatment, sex at the time of arrival (steer or banded bull), and the treatment by sex interaction, and random effects were pasture management group within block, treatment by pasture management group within block by treatment interaction, and residual. The treatment by sex interaction was not significant, and the final model considered fixed effects of treatment and sex at the time of arrival (steer or banded bull) and random effects of pasture management group within block, treatment by pasture management group within block by treatment interaction, and residual. Effects of sex were detected for some dependent variables, but because treatment by sex interactions were not significant and the effect of sex at arrival was not of primary interest, these results are not reported herein. Treatment least squares means and SE are reported. Treatment differences were evaluated with a protected 2-tailed *t*-test at the 5% level of significance.

Frequency results (i.e., categorical variables) pertaining to implant retention, death, culling, incidence of clinical disease, and number of treatments administered were analyzed by logistic regression using the PROC GLIMMIX procedure of SAS to evaluate the fixed effects of treatment and sex at the time of arrival and random effects of pasture management group within block, treatment by pasture management group within block by treatment interaction, and residual. Treatment differences were evaluated with a protected 2-tailed *t*-test at the 5% level of significance.

Supplemental feed offered was summarized but not statistically analyzed because quantities of feed refusals were not measured. Furthermore, because all treatments were equally represented within an animal management group, there was no treatment bias with respect to level of supplementation.

RESULTS AND DISCUSSION

Animal Management

Table 3 provides an overview across pasture management groups of quantities of 26% CP concentrate, ber-

Table 3. Summary of supplemental feed offered across pasture management groups

Study days ¹	Daily averages per animal		
	26% CP		
	concentrate, kg/d	Bermudagrass hay, kg/d	Mineral, ^{2,3} g/d
1 to 20	1.32	2.81	0.00
21 to 40	1.32	3.13	0.00
41 to 60	1.23	1.77	7.3
61 to 80	1.18	1.50	21.4
81 to 100	0.23	0.05	79.7
101 to 120	0.14	0.00	102.4
121 to 140	0.45	0.00	46.5
141 to 160	1.14	0.00	53.7
161 to 180	1.14	0.00	27.5
181 to 200	1.04	0.00	20.3

¹d 1 for block 1 = February 25, 2016; d 200 for block 3 = August 26, 2016.

²Western Feed Mills Inc. (Cedar Vale, KS). Feeding instructions: 91 g/d to provide 350 mg of chlortetracycline for control of bacterial pneumonia in cattle associated with shipping fever complex caused by *Pasteurella* spp. susceptible to chlortetracycline. For control of active infection of *Anaplasma marginale* susceptible to chlortetracycline in cattle less than 320 kg.

³Guaranteed analysis (90% DM basis): 18.0 to 21.6% calcium, ≥1.5% phosphorus, 18.0 to 21.6% salt, ≥1.0% magnesium, ≥0.25% potassium, ≥150 mg/kg copper, ≥400 mg/kg iodine (as ethylenediamine dihydroiodide), ≥2.2 mg/kg selenium, ≥600 mg/kg zinc, ≥110,132 IU of vitamin A/kg, and 3.85 g/kg chlortetracycline.

mudagrass hay, and mineral mix offered during each 20-d interval throughout the course of the study. During a 5-d period that included April 19 to 23, 2016, cattle were pulse dosed with medicated feed intended to deliver 22 mg of chlortetracycline/kg of BW, an approved approach for treatment of BRD. Following a 2-d period with no treatment, pulse dosing with 22 mg of chlortetracycline/kg of BW resumed for another 5-d period that included April 26 to March 1, 2016. Supplementation of pasture with bermudagrass hay and 26% CP concentrate occurred primarily during the first 70 d, when available pasture forage consisted of dormant grass. Beyond d 70 (mid-April) cattle grazed spring-summer grass, which eliminated the need to supplement with bermudagrass hay for the remainder of the study. Supplementation with 26% CP concentrate decreased dramatically during spring-summer grazing but began to increase from approximately late-June through completion of the study as grass matured.

Of 330 steers enrolled to SOG, 320 completed the study (Table 4). Six SOG steers died between enrollment and d 70 due to BRD, and an additional 4 animals were removed during processing on d 70 due to chronic BRD. No animals were removed from SOG after d 70. Of 328 steers enrolled to REVG, 314 completed the study. Eight REVG steers died from BRD between enrollment and d 70 and 1 died of septicemia; 3 others were removed during processing on d 70 due to chronic BRD. Between d 70 and termination of the study, an additional 2 animals died. Cause of death for these 2 animals could not be determined be-

cause predators damaged carcasses. Of 328 steers enrolled to ENC, 314 completed the study. Seven steers from this treatment died from BRD between enrollment and d 70 and 1 was euthanized on d 68 for humane reasons due to a broken leg; an additional 2 steers were removed during processing on d 70 due to chronic BRD. Between d 70 and termination of the study, an additional 2 animals died, but cause of death could not be determined due to carcass mutilation by predators. An additional 2 animals were not present at the time final BW were measured on d 200 and were presumed dead or lost. Overall, cause of culling or death for 30 of the 38 animals that did not complete the study was BRD, but there was no treatment-related difference in culling or death losses specifically due to BRD ($P = 0.9028$). There was no evidence that mortality ($P = 0.6202$) or culling ($P = 0.7501$) incidence was different between treatments, and as a result the number of cattle that completed the study was not different between treatments ($P = 0.6994$).

d-70 Implant Observations

Of the 324 SOG animals that were observed on d 70 (Table 5), implants were located in 300 steers, yielding a retention rate of 92.5%. A total of 319 REVG were observed on d 70, and implants were located in 307 steers, yielding a retention rate of 96.2%. Finally, of 320 ENC steers observed on d 70, implants were located in 281, yielding a retention rate of 87.8%. The number of cattle with retained implants on d 70 was different across treat-

Table 4. Summary of animal removal data

Item	Treatment ¹			P-value ²
	SOG	REVG	ENC	
No. enrolled	330	328	328	—
No. dead d 0 to 70	6	9	8	0.6202
No. culled on d 70	4	3	2	0.7501
No. present at d 70	320	316	318	0.7635
No. dead d 70 to 200	0	2	2	NE ³
No. missing at d 200	0	0	2	NE
No. present at d 200	320	314	314	0.6994
Dead or cull removal reasons				
Bovine respiratory disease	10	11	9	0.9028
Broken leg (euthanized)	0	0	1	NE
Septicemia	0	1	0	NE
Cause of death unknown due to predators	0	2	2	NE
Other unknown (missing at d 200)	0	0	2	NE

¹SOG = Synovex One Grass (Zoetis, Parsippany, NJ); REVG = Revalor-G (Merck, Madison, NJ); ENC = Encore (Elanco, Indianapolis, IN).

²Data were analyzed by logistic regression using the PROC GLIMMIX procedure of SAS (SAS Institute Inc., Cary, NC) to evaluate the fixed effects of treatment and sex at the time of arrival and random effects of pasture management group within block, treatment by pasture management group within block by treatment interaction, and residual.

³NE = nonestimable due to inadequate data to allow model convergence.

ments ($P = 0.0031$), with retention by cattle treated with ENC significantly less ($P \leq 0.05$) than REVG and SOG; implant retention was not different between REVG and SOG ($P > 0.05$). The number of SOG, REVG, and ENC cattle that lost implants was 24, 12, and 39, respectively ($P = 0.0042$); implant loss was significantly different for REVG and ENC ($P \leq 0.05$), but implant loss for SOG cattle was intermediate and not different from either REVG or ENC ($P > 0.05$). Retention of SOG implants in the present study was less than was previously shown in 2 studies by Cleale et al. (2015), where SOG implant retention rates in cattle treated by the same procedures as those used herein were 100 and 97.6%, respectively. Previous studies evaluating implant retention in cattle treated with estradiol-containing silicone implants have reported similar results to those reported here (Mathison and Stobbs, 1983). Parrott et al. (1985) reported that reduced retention of silicone implants is a function of the physical properties of the implant, hygiene during application, placement location in the ear, and physical factors (e.g., head shaking soon after treatment).

A summary of steers on each treatment showing evidence of abscesses or fluid at the implant site is presented in Table 5. Implant site abscess incidence was affected by treatment ($P = 0.0333$), with more animals treated with REVG showing evidence of abscesses at implant sites than steers treated with ENC ($P \leq 0.05$); an explanation for this observation is not evident. The number of SOG cattle with evidence of abscesses at implant sites was not different from either REVG or ENC ($P > 0.05$). Presence of

fluid at implant sites was not affected by treatment ($P = 0.1358$), nor was overall implant defect rate ($P = 0.2999$), which was defined as the sum of animals on each treatment with evidence of lost, abscessed, or fluid-surrounded implants.

BW, Weight Gain, and ADG

The primary basis for study conclusions centered on results that included all animals enrolled into the study, regardless of whether or not implants were documented missing on d 70. Body weights of cattle on d 0 were not different among treatments ($P = 0.8312$; Table 6). Similarly BW were not different on d 70 (mean = 232 ± 3.3 kg; $P = 0.9254$), indicating implants performed comparably during the early stages of the grazing period. By d 200, however, cattle treated with SOG weighed 391.2 kg, which was more than REVG cattle (380.7 kg) or cattle treated with ENC (381.4 kg; $P \leq 0.05$). Final BW of cattle treated with REVG was not different from final BW of cattle treated with ENC ($P > 0.05$).

Body weight gains from d 0 to 70 averaged 41.6 kg/steer and were not affected by treatment ($P = 0.9721$; Table 6). However, BW gained by SOG cattle over the latter 130 d of the study (159.8 kg) and over the entire 200-d study (200.2 kg) were greater than for cattle treated with REVG (150.2 and 190.7 kg, respectively) or ENC (150.1 and 190.8 kg, respectively; $P \leq 0.05$), but BW gains by REVG and ENC were not different from each other through either of these intervals. Over the 200-d study, cattle treated with

Table 5. Summary of implant status data through 70 d of study

Item	Treatment ¹			P-value ²
	SOG	REVG	ENC	
No. enrolled	330	328	328	—
Implant status				
Animals with data on d 70, no.	324	319	320	—
Lost implants, no.	24 ^{ab}	12 ^b	39 ^a	0.0042
Retained implants, no.	300 ^b	307 ^b	281 ^a	0.0031
Retention rate, %	92.5	96.2	87.8	—
Of animals with retained implants on d 70				
Abscessed, no. (%)	7 ^{ab} (2.3)	15 ^b (4.9)	3 ^a (1.1)	0.0333
With fluid, no. (%)	7 (2.3)	2 (0.7)	2 (0.7)	0.1358
Of animals with data on d 70				
Lost, abscessed, or with fluid, no.	38	29	44	0.2999
Lost, abscessed, or with fluid, %	11.7	9.1	13.8	—

^{a,b}Values in the same row with different superscripts are different ($P \leq 0.05$).

¹SOG = Synovex One Grass (Zoetis, Parsippany, NJ); REVG = Revalor to G (Merck, Madison, NJ); ENC = Encore (Elanco, Indianapolis, IN).

²Data were analyzed by logistic regression using the PROC GLIMMIX procedure of SAS (SAS Institute Inc., Cary, NC) to evaluate the fixed effects of treatment and sex at the time of arrival and random effects of pasture management group within block, treatment by pasture management group within block by treatment interaction, and residual.

SOG gained an average of 9.5 kg of BW more than steers treated with REVG or ENC ($P \leq 0.05$).

Rates of BW gain were not different ($P = 0.9721$) among treatments over the first 70 d of the study and averaged 0.58 kg/d (Table 6). Over the last 130 d of the study, however, ADG by all treatments was more than during the initial 70-d interval, likely due to increased forage quality and DM availability after d 70. Between d 70 and 200, ADG by cattle treated with SOG (1.23 kg/d) was greater ($P \leq 0.05$) than ADG for either REVG (1.16 kg/d) or ENC (1.16 kg/d). Over the entire 200-d study, cattle implanted with SOG gained 0.05 kg/d more than cattle implanted with either REVG or ENC ($P \leq 0.05$).

Table 7 summarizes ADG data over the entirety of the 200-d study based on 70-d implant observations for steers completing the study that either retained or did not retain implants. Considering only data from animals that retained implants, ADG by SOG steers was 1.01 kg/d, which was greater ($P < 0.05$) than ADG by steers treated with REVG (0.96 kg/d) or ENC (0.97 kg/d). Despite differences in proportions of implants lost between treatments and differences in ADG by steers that lost versus those that retained implants, the overall effect of lost implants on overall ADG for each treatment was between 0.00 and -0.01 kg/d. For those animals that lost implants, ADG over the entirety of the study by steers treated with SOG, REVG, or ENC were 0.84, 0.83, and 0.86 kg/d, respectively ($P = 0.7959$). If one considers ADG by animals that lost implants to be an approximate representation of growth rates for nontreated control steers, then over the 200-d grazing period the effect of implanting SOG steers

was 20.2%, the effect of implanting REVG steers was 15.7%, and the effect of implanting ENC steers was 12.8%.

Cleale et al. (2012) showed that addition of the polymer coating to 8-pellet implants containing 28 mg of estradiol benzoate and 200 mg of trenbolone acetate effectively modified payout of estradiol benzoate and trenbolone acetate from approximately 120 d for traditional uncoated implants (Synovex Plus; Zoetis) to up to 200 d with coated implants containing the same doses of active ingredients (Synovex One Feedlot; Zoetis). Later, Cleale et al. (2015) showed in pastured steers implanted with SOG that ADG increased over 200-d grazing periods by 20.5% compared with sham-implanted controls in one study and 16.7% in a second study, results that are similar to the present study. Data pooled from 4 studies conducted to evaluate product efficacy showed that over 107- to 116-d grazing periods, ADG by steers treated with REVG (0.94 kg/d) was 14.6% more than ADG by negative controls (0.82 kg/d; FDA, 1996), a result similar to the effect of REVG in the present study. Kuhl (1997) also presented data from 94-d grazing studies showing ADG by steers implanted with REVG (0.75 kg/d) was 16.1% more than nonimplanted controls (0.65 kg/d). Increased ADG of 11 to 15% by steers treated with estradiol-containing silicone implants such as Compudose and ENC (also referred to as Compudose 400) were shown by Utley et al. (1980) and Mathison and Stobbs (1983).

Morbidity Data

Over the course of the study, approximately 29% of animals enrolled were treated at least once for BRD, pink-

Table 6. Summary of weight gain data for animals that completed the study (least squares means $\pm$ SE excluding dead and culled cattle)

Item	Treatment ¹			P-value
	SOG	REVG	ENC	
No. completing study (200 d)	320	314	314	—
BW, kg				
d 0	191.2 $\pm$ 2.3	190.1 $\pm$ 2.3	190.7 $\pm$ 2.3	0.8312
d 70	232.1 $\pm$ 3.3	231.2 $\pm$ 3.3	232.0 $\pm$ 3.3	0.9254
d 200	391.2 $\pm$ 8.8 ^a	380.7 $\pm$ 8.8 ^b	381.4 $\pm$ 8.8 ^b	0.0034
Weight gain, kg/steer				
d 0 to 70	40.4 $\pm$ 3.3	40.6 $\pm$ 3.3	40.8 $\pm$ 3.3	0.9721
d 70 to 200	159.8 $\pm$ 10.5 ^a	150.2 $\pm$ 10.5 ^b	150.1 $\pm$ 10.5 ^b	<0.0001
d 0 to 200	200.2 $\pm$ 9.0 ^a	190.7 $\pm$ 9.0 ^b	190.8 $\pm$ 9.0 ^b	0.0013
ADG, kg/d				
d 0 to 70	0.58 $\pm$ 0.05	0.59 $\pm$ 0.05	0.58 $\pm$ 0.05	0.9721
d 70 to 200	1.23 $\pm$ 0.08 ^a	1.16 $\pm$ 0.08 ^b	1.16 $\pm$ 0.08 ^b	<0.0001
d 0 to 200	1.00 $\pm$ 0.04 ^a	0.95 $\pm$ 0.04 ^b	0.95 $\pm$ 0.04 ^b	0.0013

^{a,b}Means in the same row with different superscripts are different by protected *t*-test ($P < 0.05$).

¹SOG = Synovex One Grass (Zoetis, Parsippany, NJ); REVG = Revalor-G (Merck, Madison, NJ); ENC = Encore (Elanco, Indianapolis, IN).

Table 7. Summary of ADG by steers completing the study that did or did not lose implants before d 70 (least squares means $\pm$ SE excluding dead and culled cattle)

Item	Treatment ¹			P-value
	SOG	REVG	ENC	
Retained implants				
No. of steers	297	302	275	—
ADG, kg/d	1.01 $\pm$ 0.05 ^a	0.96 $\pm$ 0.05 ^b	0.97 $\pm$ 0.05 ^b	0.0012
Lost implants				
No. of steers	23	12	39	—
ADG, kg/d	0.84 $\pm$ 0.06	0.83 $\pm$ 0.07	0.86 $\pm$ 0.06	0.7959
ADG, % increase above lost	20.2	15.7	12.8	—

^{a,b}Means in the same row with different superscripts are different by protected *t*-test ($P < 0.05$).

¹SOG = Synovex One Grass (Zoetis, Parsippany, NJ); REVG = Revalor-G (Merck, Madison, NJ); ENC = Encore (Elanco, Indianapolis, IN).

eye, or foot rot, but overall frequencies were not different between treatments ($P = 0.9384$; Table 8). Data also did not show any treatment-related differences on the number of cattle treated at least twice ($P = 0.9827$) or at least 3 times for these disorders ($P \geq 0.1761$). For respiratory disease, approximately 14% of SOG cattle, 16% of REVG cattle, and 16% of ENC cattle were treated, respectively ($P = 0.7124$). Likewise for pinkeye, 5, 4, and 5% of cattle were treated, respectively, with SOG, REVG, and ENC ($P = 0.8394$). Incidence of foot rot was low overall and not different between treatments ($P = 0.3274$).

Partial Budget Economic Analysis

Table 9 summarizes the partial budget analysis based on average purchase price paid for cattle enrolled into the study, average sale value of cattle as feeders after 200 d on study, internet retailer prices for implant treatments, and estimated morbidity expenses (medicines, supplies, and labor). Calculations were performed both with and without consideration of dead and culled animals. Assumptions used in calculations are presented as footnotes to Table 9. Average purchase price for stockers averaged about \$932

Table 8. Summary of morbidity data

Item	Treatment ¹			P-value ²
	SOG	REVG	ENC	
No. enrolled	330	328	328	—
Treated at least once, no. (%)	93 (28.4)	97 (29.4)	92 (28.0)	0.9384
Treated at least twice, no. (%)	26 (10.0)	28 (10.5)	28 (10.2)	0.9827
Treated at least thrice, no. (%)	1 (0.4)	4 (1.6)	7 (2.8)	0.1761
Respiratory disease				
Treated at least once, no. (%)	48 (14.3)	55 (16.3)	57 (16.4)	0.7124
Treatments given, no. (no./enrollee)	60 (0.177)	73 (0.217)	74 (0.216)	0.4705
Pinkeye				
Treated at least once, no. (%)	17 (4.8)	21 (4.2)	20 (5.3)	0.8394
Treatments given, no. (no./enrollee)	21 (0.058)	27 (0.053)	27 (0.069)	0.7328
Foot rot				
Treated at least once, no. (%)	21 (1.4)	13 (0.5)	12 (0.1)	0.3274
Treatments given, no. (no./enrollee)	30 (0.019)	19 (0.010)	21 (0.012)	0.4644

¹SOG = Synovex One Grass (Zoetis, Parsippany, NJ); REVG = Revalor-G (Merck, Madison, NJ); ENC = Encore (Elanco, Indianapolis, IN).

²Data were analyzed by logistic regression using the PROC GLIMMIX procedure of SAS (SAS Institute Inc., Cary, NC) to evaluate the fixed effects of treatment and sex at the time of arrival and random effects of pasture management group within block, treatment by pasture management group within block by treatment interaction, and residual.

Table 9. Partial budget economic analysis of treatment choice (least squares means $\pm$ SE)

Item	Treatment ¹			P-value
	SOG	REVG	ENC	
Deaths and culls excluded				
Stocker purchase price at \$221.75/45.4 kg, ² \$	934.59 $\pm$ 11.05	929.33 $\pm$ 11.07	932.22 $\pm$ 11.08	0.8312
Feeder sale price at \$142.50/45.4 kg, ² \$	1,228.97 $\pm$ 27.60 ^a	1,196.04 $\pm$ 27.61 ^b	1,198.04 $\pm$ 27.62 ^b	0.0034
Gross value of weight gained, \$/animal	294.82 $\pm$ 28.58 ^a	266.91 $\pm$ 28.58 ^b	266.09 $\pm$ 28.59 ^b	0.0027
Implant cost, ³ \$/dose	4.95	1.39	3.00	—
Value of gain minus implant cost, \$	289.87 $\pm$ 28.58 ^a	265.52 $\pm$ 28.58 ^b	263.09 $\pm$ 28.59 ^b	0.0067
Morbidity cost, ⁴ \$/animal	6.17 $\pm$ 0.90	6.15 $\pm$ 0.90	6.39 $\pm$ 0.90	0.9360
Value of gain minus implant and morbidity cost, \$	283.21 $\pm$ 29.75 ^a	258.92 $\pm$ 29.75 ^b	256.24 $\pm$ 29.76 ^b	0.0075
Deaths and culls included ⁵				
Stocker purchase price at \$221.75/45.4 kg, ² \$	933.28 $\pm$ 10.99	927.48 $\pm$ 10.99	928.95 $\pm$ 11.00	0.7774
Feeder sale price at \$142.50/45.4 kg, ² \$	1,199.75 $\pm$ 27.18 ^a	1,150.69 $\pm$ 27.18 ^b	1,156.75 $\pm$ 27.23 ^b	0.0290
Gross value of weight gained, \$/animal	266.46 $\pm$ 28.71 ^a	223.20 $\pm$ 28.72 ^b	227.60 $\pm$ 28.77 ^b	0.0322
Implant cost, ³ \$/dose	4.95	1.39	3.00	—
Value of gain minus implant cost, \$	261.51 $\pm$ 28.72 ^a	221.81 $\pm$ 28.72 ^b	224.60 $\pm$ 28.77 ^b	0.0490
Morbidity cost, ⁴ \$/animal	6.79 $\pm$ 0.85	7.25 $\pm$ 0.85	7.26 $\pm$ 0.85	0.7749
Value of gain minus implant and morbidity cost, \$	254.15 $\pm$ 29.85 ^a	213.80 $\pm$ 29.86 ^b	216.63 $\pm$ 29.90 ^b	0.0521

^{a,b}Means in the same row with different superscripts are different by protected or unprotected *t*-tests ($P < 0.05$).

¹SOG = Synovex One Grass (Zoetis, Parsippany, NJ); REVG = Revalor-G (Merck, Madison, NJ); ENC = Encore (Elanco, Indianapolis, IN).

²Cattle prices are the average paid for 193-kg steers when the study started, \$4.88/kg; value at completion of the study was the average sale price received for 386-kg steers, \$3.14/kg.

³Implant prices obtained from www.valleyvet.com on September 18, 2016.

⁴Cattle were treated for bovine respiratory disease, pinkeye, and foot rot with Draxxin (Zoetis), Nuflor (Merck), Excenel (Zoetis), or Noromycin 300 LA (Norbrook, Overland Park, KS); antibiotic prices were obtained at www.valleyvet.com on September 18, 2016. Morbidity costs were based on dose administered, route of administration, and assumed labor costs at \$20/man-hour. See Table 8 for a summary of number of animals treated and number of treatments administered to each treatment group.

⁵All culls were removed after weighing during processing on d 70. Culls were assigned a value of \$3.14/kg, and value at time of removal was computed based on d-70 BW. Loss on dead animals was estimated as purchase price and no return.

per animal and was not different between treatments. At study termination, however, cattle treated with SOG were valued at \$1,229 each, whereas those treated with either REVG or ENC were valued at approximately \$1,197 ($P = 0.0034$). Subtracting purchase price of stockers from the value of feeder cattle yielded gross value of the BW gained, which was \$295 for SOG and \$267 for REVG and ENC; value of gain for SOG was greater than REVG or ENC ($P < 0.05$). Value of BW gained after consideration of the implant costs for each treatment showed that gross value of animals treated with SOG remained significantly more than that for REVG and ENC. Costs associated with therapeutic treatments averaged about \$6 per enrolled animal and were not different among treatments ($P > 0.9360$). The final calculation, which was the value of BW gained minus implant and therapeutic treatment costs, showed that value of BW gain was \$283 for cattle treated with SOG, \$259 for cattle treated with REVG, and \$256 for cattle treated with ENC; SOG was greater than REVG and ENC ($P < 0.05$), but REVG and ENC

were not different from each other. The SOG treatment increased the value of cattle by over \$24 compared with REVG and increased the value of cattle by over \$26 compared with ENC. Conducting computations in a manner that reflected economic losses associated with culled and dead cattle increased the net treatment effect of SOG after implant and morbidity expenses compared with REVG (\$40) or ENC (\$38; $P = 0.0521$).

IMPLICATIONS

Through the first 70 d, ADG was similar for all treatment groups, but under the conditions of this study, a single dose of SOG resulted in ADG over the complete 200-d grazing period of 1.01 kg/d, whereas ADG by steers treated with a single dose of either REVG or ENC were both 0.96 kg/d. Thus, during this 200-d study ADG by SOG cattle was 5.2% more than ADG by REVG or ENC cattle. Because cattle treated with SOG grew faster, their gross value at the end of the study was more than other

treatments studied by at least \$24/animal. There was no effect of treatments on morbidity, mortality, or culling rate, and there were no observed adverse effects attributable to experimental treatments.

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