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C. L. Maxwell

Oklahoma State University

B. C. Wilson

Oklahoma State University

C. F. O'Neill

Oklahoma State University

B. K. Wilson

Oklahoma State University

C. G. Hixon

Oklahoma State University

See next page for additional authors

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Authors

C. L. Maxwell, B. C. Wilson, C. F. O'Neill, B. K. Wilson, C. G. Hixon, C. L. Haviland, A. N. Grimes, M. S. Calvo-Lorenzo, D. L. VanOverbeke, G. G. Mafi, C. J. Richards, D. L. Step, B. P. Holland, and C. R. Krehbiel

The effects of technology use in feedlot production systems on feedlot performance and carcass characteristics¹

C. L. Maxwell,* B. C. Bernhard,* C. F. O'Neill,*
B. K. Wilson,* C. G. Hixon,* C. L. Haviland,* A. N. Grimes,* M. S. Calvo-Lorenzo,*
D. L. VanOverbeke,* G. G. Mafi,* C. J. Richards,* D. L. Step,† B. P. Holland,‡ and C. R. Krehbiel*²

*Department of Animal Science, Oklahoma State University, Stillwater 74078;

†Department of Veterinary Clinical Sciences, Oklahoma State University, Stillwater 74078; and ‡Merck Animal Health, DeSoto, Kansas 66018

ABSTRACT: The objectives of this study were to examine the effects of feedlot production systems with and without the use of a β -adrenergic agonist compared to an all-natural production program on feedlot performance and carcass characteristics. Crossbred beef steers ($n = 336$; initial BW = 379 ± 8 kg) were randomized to 1 of 3 treatments in a randomized complete block design (RCBD; 14 steers/pen; 8 pens/treatment). Treatments consisted of an all-natural treatment (NAT), a conventional treatment (CONV), and a conventional treatment with a β -agonist (CONV-Z). All treatments were fed the same basal diet with NAT cattle receiving no growth promoting technologies. The CONV and CONV-Z cattle were implanted with 40 mg of estradiol and 200 mg of trenbolone acetate (TBA) on d 0 and were fed 33 and 9 mg/kg of monensin and tylosin daily, respectively. The CONV-Z cattle were fed zilpaterol hydrochloride (ZH) at 6.76 mg/kg (90% DM basis) for the last 20 days on feed (DOF). There was no effect of treatment on DMI ($P = 0.83$); however, CONV-Z steers gained 3.8% faster (1.64 vs. 1.58 kg/d; $P < 0.01$) and were 5.3% more efficient (0.160 vs. 0.152; $P < 0.01$) than CONV steers, and CONV steers gained 32.8% faster (1.58 vs. 1.19 kg/d; $P < 0.01$) and were 26.7%

more efficient (0.152 vs. 0.120; $P < 0.01$) than NAT steers. There was a 35.7% improvement in estimated carcass gain (1.29 vs. 0.95 kg/d; $P < 0.01$) and a 32.6% improvement in carcass efficiency (0.126 vs. 0.095; $P < 0.01$) for CONV-Z steers compared to NAT steers. Hot carcass weight was increased by 8 kg for CONV-Z steers compared to CONV steers (394 vs. 386 kg; $P = 0.05$) and 46 kg compared to NAT steers (394 vs. 348 kg; $P < 0.01$). Longissimus muscle area was increased by 3.6 cm² for CONV-Z steers compared to CONV steers (92.29 vs. 88.67 cm²; $P = 0.02$) and 12.1 cm² for CONV-Z steers compared to NAT steers (92.29 vs. 80.16 cm²; $P < 0.01$), resulting in a 9.6% unit increase in USDA yield grade (YG) 1 (15.14 vs. 5.52%; $P < 0.05$) and a 21.6% unit reduction in USDA YG 3 for CONV-Z steers compared to CONV steers (30.70 vs. 52.32%; $P < 0.05$). The CONV-Z steers had a lower marbling score compared to the other treatments (432; $P < 0.01$), resulting in an 11.7% unit increase (20.70 vs. 9.03%; $P < 0.05$) in USDA Select carcasses compared to CONV steers. The results of this experiment show that CONV-Z and CONV production results in a significant improvement in feedlot performance and USDA YG compared to NAT.

Key words: beef cattle, beta-adrenergic agonist, conventional, efficiency enhancing technologies, natural

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INTRODUCTION

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²Corresponding author: clint.krehbiel@okstate.edu

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Efficiency enhancing technologies have been used in beef production in the United States since diethylstilbestrol was approved in the 1950s (Raun and Preston, 2002). Zeranone implants were first used in cattle in 1969, and in the 1980s and 1990s the use of estradiol/trenbolone acetate (TBA) combination implants

became popular. Most recently, nutritionists and feedlot management have adopted the use of two β -adrenergic agonists (**BAA**; ractopamine hydrochloride, approved 2003, and zilpaterol hydrochloride [**ZH**], approved 2006; Johnson et al., 2013). Capper (2011) compared resource use and beef production from 1977 to 2007 and found that beef production in 2007 required only 69.9% of animals and 67% of land to produce 1 billion kg of beef compared to 1977. Moreover, average beef yield per animal increased from 274 to 351 kg. According to USDA/NASS (2014), beef slaughter production in 1950 was 4.3 billion kg of beef, and in 2012 it was estimated at 11.7 billion kg. These drastic improvements in production efficiency partially stems from the development and adoption of new technologies.

Most recently, Maxwell et al. (2014) examined the effects of an all-natural system (without use of growth implants, β -agonists, and ionophores) compared to a confined conventional system with the use of a BAA and differing roughage levels, beginning at the stocker phase, through feedlot production and carcass characteristics. However, few data exist examining conventional production systems with and without the use of a BAA compared to an all-natural system on feedlot performance and carcass characteristics. The objectives of the current study were to examine the effects of confined beef production systems similar to those reported in Maxwell et al. (2014), with and without the use of a BAA, on feedlot performance and carcass characteristics compared to a confined all-natural production system.

MATERIALS AND METHODS

All protocols were approved by the Oklahoma State University Institutional Animal Care and Use Committee.

Cattle Management

On April 26 and April 29, 2013, 303 black-hided certified natural steers were transported 1046 km from Willow Lake, SD, and 120 black-hided certified natural steers were transported 692 km from Cedar Rapids, NE to the Willard Sparks Beef Research Center, Stillwater, OK. Upon arrival, cattle were weighed on a pen scale, placed in holding pens, and fed prairie hay and a receiving ration containing no monensin or tylosin. The cattle experienced a 4.1 and 4.6% shrink from pay weights recorded in South Dakota and Nebraska, respectively. The morning after arrival, each group was weighed and individually identified with a visual numbered tag as well as an electronic identification (**EID**) tag. On May 1 and May 3, 2013, all steers were vaccinated against clostridial toxins (Vision 7, Merck Animal Health, DeSoto, KS), infectious bovine rhinotracheitis (**IBR**), parainfluenza-3 virus (**PI3**), bovine respiratory syncytial virus (**BRSV**), and bovine viral diarrhea virus (**BVD**) type I and II *Mannheimia haemolytica* and *Pasteurella multocida* (Vista Once, Merck Animal Health), and treated for internal parasites (Safeguard, Merck Animal Health) and external parasites (Ivomec Plus, Merial Animal Health, Duluth, GA). The cattle from South Dakota were sorted into 7 weight groups, and the cattle from Nebraska were sorted into 3 weight groups. Eighty-seven steers were sorted off to be used for another experiment. The remaining 336 steers were started on the experiment on 3 different dates, May 7, 9, and 23, 2013. The lightest remaining cattle from the South Dakota group were held on the receiving diet until May 23, 2013. Steers were weighed, and chute temperament, exit speed, and hide score were obtained on d -1. The cattle were blocked by BW within source; stratified by initial temperament, exit speed, and hide scores; and randomly allocated to study pens. On d 0, all cattle were weighed and randomly sorted to study pens (8 blocks; 1 replication/block; 8 pens/treatment; 14 steers/pen; 112 steers/treatment; initial BW = 379 ± 8 kg). Treatments consisted of an all-natural treatment (**NAT**), a conventional treatment (**CONV**), or a conventional treatment with the addition of a β -agonist for the last 20 d on feed (**CONV-Z**). All treatments were cattle fed in a confinement situation. The NAT cattle received no antibiotics, growth implants, or β -agonists, and if antibiotic treatment was deemed necessary, they were removed from the trial. The CONV and CONV-Z cattle were implanted with 40 mg of estradiol and 200 mg of TBA (Revalor-XS, Merck Animal Health) on d 0. They were also daily fed 33 and 9 mg/kg of monensin and tylosin (Rumensin and Tylan, Elanco Animal Health, Greenfield, IN), respectively. The CONV and CONV-Z cattle were eligible for antibiotic treatment if deemed as necessary. The CONV-Z cattle were fed ZH (Zilmax, Merck Animal Health) at 6.76 mg/kg (90% DM basis) for the last 20 d on feed, and ZH was withdrawn from feed for 3 to 5 d before slaughter. All cattle were fed the same base 93% concentrate diet (Table 1). Cattle were housed in twenty-four 12.2×30.5 m soil-surfaced feedlot pens with 12.2-m fence-line concrete feed bunks with a 76-L concrete fence-line water tank (Model J 360-F, Johnson Concrete, Hastings, NE) shared between two pens.

Cattle were weighed on d 28, 56, and 84 of the finishing phase. On d 84, cattle were projected into slaughter groups based on projected slaughter BW and a visual appraisal of 12th rib fat thickness (**FT**). On August 19 and 20, 2013, d 103 and 104, respectively, all cattle except for the light 2 blocks from South Dakota were weighed and the CONV-Z cattle were started on ZH. The light 2 blocks were weighed and the CONV-Z started on ZH on October 08, 2013 (d 138). This date is referenced as d 0Z. The cattle were

Table 1. Ingredient composition (percent DM basis) of diets fed¹

Ingredient	Experimental diet ²		
	NAT	CONV	CONV-Z ³
Dry-rolled corn	47.86	47.84	47.84
Switchgrass hay	6.88	6.88	6.88
Dried distillers grains	14.60	14.60	14.60
Sweet Bran ⁴	15.15	15.15	15.15
Liquid supplement	10.37	10.37	10.37
Dry supplement, B-272 ⁵	5.14	—	—
Dry supplement, B-273 ⁶	—	5.17	5.17

¹Actual DM formulation calculated based on as-is formulations and weekly ingredient DM values.

²Treatments include: 1) Natural—no antibiotics, ionophores, growth implants, or beta-agonists (NAT), 2) Conventional—fed tylosin, monensin, received growth implant, no beta-agonist (CONV), and 3) Conventional w/ zilpaterol—fed tylosin, monensin, received growth implant, fed zilpaterol hydrochloride (87.6 mg/steer last 20 day on feed [DOF]; CONV-Z).

³Conventional w/Zilmax contained 6.76 mg/kg (90% DM basis) fed last 20 DOF with a 3-d withdrawal.

⁴Cargill, Inc., Minneapolis, MN.

⁵Formulated to contain (DM basis): 6.92% urea, 29.86% limestone, 1.03% MgO, 0.38% salt, 0.119% copper sulfate, 0.117% MnO, 0.05% selenium premix (0.6% Se), 0.618% ZnSO₄, 0.311% vitamin A (30 IU/mg), 0.085% vitamin E (500 IU/g), 0% Rumensin 90, 0% Tylan 40, 39.46% ground corn, and 21.04% wheat middlings.

⁶Formulated to contain (DM basis): 6.92% urea, 30.36% limestone, 1.03% MgO, 0.38% salt, 0.119% copper sulfate, 0.116% MnO, 0.05% selenium premix (0.6% Se), 0.618% ZnSO₄, 0.311% vitamin A (30 IU/mg), 0.085% vitamin E (500 IU/g), 0.317% Rumensin 90, 0.195% Tylan 40, 38.46% ground corn, and 21.04% wheat middlings.

then weighed on d 10Z and d 20Z. Cattle on CONV-Z were fed ZH at a calculated rate of 87.6 mg·steer⁻¹·d⁻¹ based on calculated intake and assayed ZH values with a 3- to 5-d period of ZH withdrawal. A 4% pencil shrink was applied to all BW for calculation of performance. Performance was calculated on mortality and removals included basis, as BW were obtained at time of death or removal from each animal.

Cattle were fed for an average of 136 d. The cattle were slaughtered in two separate groups. The first group (6 blocks) was slaughtered on September 12 and 13, 2013, and the second group (2 blocks) was slaughtered on October 31 and Nov 01, 2013. All cattle were shipped 108 km to Creekstone Farms, Arkansas City, KS for slaughter. The CONV and CONV-Z cattle were slaughtered on the respective Thursday, and the NAT cattle were slaughtered on the Friday of each week. This difference in shipping date was due to the requirements of the packing facility in that they only slaughter NAT cattle on the Friday of each week. All cattle were weighed before shipment. The BW obtained on d 20Z was utilized as the final live BW since all cattle were weighed on the same day. However, due to potential fill differences, the BW obtained the morning of slaughter was used for calculation of dressing percentage. Dressing percentage was

adjusted to the average of the pen and HCW recalculated for any animal noted as having excessive trim at slaughter, as noted by trained university personnel. This was determined if an animal was noted as having trim and dressing percentage was lower than the average of the pen. Carcass data were collected by trained Creekstone personnel using an E+V vision grading camera (VBG2000, E+V Technology; Oranienburg, Germany). Liver scores were obtained by the methods as in Maxwell et al. (2014).

Feed and Bunk Management

Cattle were adapted to the assigned finishing ration during an 18-d adaption period. During this phase, CONV calves were fed a portion of a base receiving ration (15% dry-rolled corn, 49.8% wet-corn gluten feed, 5.2% supplement, and 30% ground sorghum or prairie hay, DM basis) with Rumensin and Tylan and their treatment diet, and the NAT calves were fed the same receiving ration without Rumensin or Tylan and their treatment diet. This was accomplished using a 2-ration blend method. Each day, the treatment ration was increased by 5.6% DM, and the receiving ration was decreased by 5.6% DM until calves were adapted to the finishing ration. Following adaptation, calves were fed twice daily at 0700 and 1300 h. Feed was mixed and delivered in a 274-12 Roto-Mix mixer wagon (Roto-Mix, Dodge City, KS) and delivered to each pen with delivery accuracy to the nearest 0.454 kg. Feeding order was NAT, CONV, and CONV-Z at each feeding. Flush batches were utilized at the end of each feeding to ensure no cross contamination of treatment rations. Feed bunks were managed to contain trace amounts of feed, and bunks were cleaned before each feeding to remove manure, hair, etc. Bunk dividers were utilized and feed was only placed in the middle 11 m of the feed bunk for a 1.2-m area of empty bunk to further ensure no cross contamination occurred. Zilpaterol hydrochloride was added to a type-B pelleted supplement at 160 mg/kg (as-is basis) to accomplish a 6.8 mg/kg (90% DM basis) type-C complete feed. This type-B pelleted supplement was the same supplement fed to the CONV and NAT, with the exception of the difference in Rumensin, Tylan, and ZH per treatment designation. All steers were fed a direct-fed microbial (Bovamine, Nutrition Physiology Company, Guymon, OK) at 1 g·steer⁻¹·d⁻¹. Direct-fed microbial delivery was accomplished by mixing the Bovamine dose with 2.26 kg of ground corn in a KitchenAid mixer (KitchenAid, St. Joseph, MI) for 5 min and adding that mixture as 2.26 kg of the called weight for dry-rolled corn in each batch of feed. This was performed during only the morning feeding.

All rations were formulated to meet or exceed NRC (2000) requirements. For all rations, minerals, vitamins,

and feed additives were contained in a ground corn and wheat-middling based pelleted supplement mixed at the Oklahoma State University Feed Mill.

Ration samples were collected once/week, dried in a forced air oven for 48 h at 60°C to determine DM. Average DM was calculated for the feeding period, and actual DMI consumption was calculated at the end of the study by dividing total kilograms of feed consumed by total head days of a pen. Ration samples were composited gravimetrically and analyzed at a commercial lab (Servi-Tech, Inc. Dodge City, KS) for nutrient composition. Samples were assayed for monensin concentration (Covance Labs, Greenfield, IN) and ZH (Merck Pharmaceutical Laboratory; Lawrence, KS). Orts were obtained on each weigh day and during inclement weather events. Dry matter was obtained, and feed was removed from total feed delivered for accurate DMI calculation. All performance calculations are the same as those described in Maxwell et al. (2014). Estimated carcass gain and feed efficiency were calculated by estimating dressing percentage using the equation described by Parr et al. (2011; predicted dress = $[0.03 \times 4\% \text{ shrunk BW, kg}] + 46.742$). The equations described by Zinn (1992) and NRC (2000) were used to determine dietary NE_m and NE_g .

Feedlot Diet Analyses

Tables 1 and 2 show the actual diet DM formulation and analyzed nutrient composition throughout the study. These rations were formulated to meet or exceed NRC requirements (NRC, 2000). Across all treatments, the diets were formulated to be the same, except for monensin and tylosin inclusion in the CONV diet and monensin, tylosin, and ZH for the last 20 d of feed for CONV-Z.

Feed samples were collected for monensin and ZH assays periodically throughout the study. No monensin was detected in the NAT rations with a reported value <0.9 mg/kg. Monensin concentration for CONV and CONV-Z diets were 24.73 mg/kg DM, less than the 33 mg/kg formulated. Calculated monensin intake with the assayed value of 24.73 mg/kg was $283 \text{ mg} \cdot \text{steer}^{-1} \cdot \text{d}^{-1}$ monensin, lower than the manufacturer recommended dose of $360 \text{ mg} \cdot \text{steer}^{-1} \cdot \text{d}^{-1}$ monensin.

Zilpaterol hydrochloride was assayed from the composited weekly samples collected during the period when ZH was fed. The assayed value (90% DM basis) was 6.76 mg/kg, very similar to the formulated value of 6.8 mg/kg. Based on actual DMI intake during the ZH period, ZH intake was $87.6 \text{ mg} \cdot \text{steer}^{-1} \cdot \text{d}^{-1}$, within the labeled dose of 60 to 90 $\text{mg} \cdot \text{steer}^{-1} \cdot \text{d}^{-1}$.

Table 2. Analyzed nutrient composition of diets fed

Item ²	Experimental diet ¹		
	NAT	CONV	CONV-Z ³
DM, %	81.08	81.14	81.29
CP, %	18.90	19.00	19.00
NPN, %	2.50	2.50	2.55
ADF, %	11.40	11.20	11.25
NDF, %	20.80	21.10	20.75
Fat, %	5.45	5.45	5.50
Ca, %	0.58	0.61	0.66
P, %	0.50	0.51	0.49
Mg, %	0.29	0.28	0.27
K, %	0.98	0.97	0.95
S, %	0.30	0.29	0.28
Monensin, mg/kg	0.00	33.00	33.00
Tylosin, mg/kg	0.00	9.00	9.00

¹Treatments include: 1) Natural—no antibiotics, ionophores, growth implants or beta-agonists (NAT), 2) Conventional—fed tylosin, monensin, received growth implant, no beta-agonist (CONV), and 3) Conventional w/ zilpaterol—fed tylosin, monensin, received growth implant, fed zilpaterol hydrochloride (87.6 mg/steer last 20 days on feed; CONV-Z).

²All values except for DM are on a 100% DM basis. Samples were chemically analyzed at a commercial laboratory (Servi-Tech Labs Inc. Dodge City, KS). Samples were composited from weekly samples collected across trial period and analyzed in duplicate.

³Ration was analyzed to contain 6.76 mg/kg (90% DM basis) zilpaterol hydrochloride, which was fed for the last 20 d on feed, followed by a 3-d withdrawal.

Statistical Analysis

All animal performance data were analyzed as a randomized complete block design (**RCBD**) using PROC MIXED (SAS 9.3, SAS Inst. Inc., Cary, NC). Pen was considered the experimental unit, and weight block was included as a random effect. All carcass data were analyzed with pen as the experimental unit and weight block included as a random effect. The USDA quality grade, yield grade (YG), and liver scores were analyzed using PROC GLIMMIX (SAS 9.3, SAS Inst. Inc.). Differences were considered significantly different when $P < 0.05$ and a trend when $0.05 \geq P \leq 0.10$.

RESULTS

There were 3 steers that died during the study (1 NAT and 2 CONV-Z) with necropsy indicating bloat as the cause of death for all three steers. One of the CONV-Z steers died before feeding ZH, while 1 died during ZH feeding (d 11Z). Two steers were removed from the trial for lameness (1 CONV and 1 NAT) and were treated with an antibiotic. No animals required antibiotic treatment for respiratory disease. At slaughter, 1 CONV-Z steer broke his leg in transport to the slaughter facility and was euthanized, and 1 CONV steer was rejected by the slaughter facility due to failure to meet hide color specifications. This animal was

Table 3. The effects of treatment on body weights, mortalities, and removals included¹

Item	Treatment ²			SE ³	P-value ³
	NAT	CONV	CONV-Z		
Pens	8	8	8	—	—
Total head	112	112	112	—	—
Days on feed	136	136	136	—	—
BW, kg ⁴					
Initial	379	379	378	8.02	0.54
d 28	432 ^a	443 ^b	443 ^b	10.97	<0.01
d 56	456 ^a	478 ^b	476 ^b	9.48	<0.01
d 84	486 ^a	521 ^b	516 ^b	10.32	<0.01
d 0Z	522 ^a	567 ^b	565 ^b	6.35	<0.01
d 10Z	529 ^a	581 ^b	583 ^b	5.76	<0.01
d 20Z	540 ^a	592 ^b	600 ^b	6.60	<0.01

^{a-c}Within a row, means without a common superscript differ ($P < 0.05$).

¹Data were analyzed with mortalities (3 digestive) and removals (2 lame) included; final BW for these removals was obtained at time of removal, and average dressing percentage was used to calculate HCW at time of removal.

²Treatments include: 1) Natural—no antibiotics, ionophores, growth implants, or beta-agonists (NAT), 2) Conventional—fed tylosin, monensin, received growth implant, no beta-agonist (CONV), and 3) Conventional w/ zilpaterol—fed tylosin, monensin, received growth implant, fed zilpaterol hydrochloride (87.6 mg/steer last 20 days on feed; CONV-Z).

³Standard error of the mean ($n = 8$). P value is for overall ANOVA.

⁴A calculated shrink of 4% was applied to all measured BW.

not slaughtered at the time of the other cattle and thus no carcass data was reported. This animal was included in all performance data.

Feedlot Performance: Live Basis

Body weights collected throughout the experiment are shown in Table 3. As expected, initial BW did not differ across treatments (379 ± 8 kg; $P = 0.54$). Beginning on d 28, CONV and CONV-Z steers had heavier BW throughout the experiment, with a 56 kg heavier BW at d 20Z compared to NAT (596 vs. 540 kg; $P < 0.01$). There was no difference in BW between CONV and CONV-Z steers throughout the experiment ($P \geq 0.16$). Interim and overall feedlot performance is shown in Table 4. Throughout the experiment, there was no effect of treatment on DMI ($P \geq 0.26$), except for when ZH was fed (d 0Z to 20Z; $P < 0.01$). During this period, the CONV and CONV-Z steers consumed more feed than the NAT steers (11.00 and 10.58 vs. 9.70 kg/d, respectively; $P \leq 0.04$). During the period in which ZH was fed, DMI was not different between CONV-Z and CONV (10.58 vs. 11.00 kg; $P = 0.41$). During this same period, there was a trend for an improvement in ADG for CONV-Z steers compared to CONV steers (1.80 vs. 1.26 kg/d; $P = 0.09$). Feed efficiency was improved by 45.6% for CONV-Z steers compared to CONV steers (0.166 vs. 0.114; $P < 0.01$) during d 0Z to d 20Z. Feed

Table 4. The effects of treatment on live feedlot performance, mortalities, and removals included¹

Item	Treatment ²			SE ³	P-value ³
	NAT	CONV	CONV-Z		
d 0–28					
DMI, kg/d	9.97	9.96	10.00	0.14	0.83
ADG, kg/d	1.92 ^a	2.30 ^b	2.31 ^b	0.17	<0.01
G:F, kg/kg	0.192 ^a	0.230 ^b	0.230 ^b	0.017	<0.01
d 28–56					
DMI, kg/d	9.88	9.98	9.72	0.27	0.51
ADG, kg/d	0.84 ^a	1.26 ^b	1.17 ^b	0.11	<0.01
G:F, kg/kg	0.086 ^a	0.128 ^b	0.121 ^b	0.011	<0.01
d 56–84					
DMI, kg/d	10.09	10.27	10.24	0.27	0.88
ADG, kg/d	1.07 ^a	1.54 ^b	1.43 ^b	0.07	<0.01
G:F, kg/kg	0.106 ^a	0.149 ^b	0.140 ^b	0.006	<0.01
d 84–0Z					
DMI, kg/d	10.49	10.99	10.98	0.25	0.26
ADG, kg/d	1.35 ^a	1.65 ^b	1.75 ^b	0.07	<0.01
G:F, kg/kg	0.129 ^a	0.150 ^b	0.160 ^b	0.005	<0.01
d 0Z–20Z					
DMI, kg/d	9.70 ^a	11.00 ^b	10.58 ^b	0.37	<0.01
ADG, kg/d ⁴	0.94 ^a	1.26 ^b	1.80 ^b	0.17	<0.01
G:F, kg/kg	0.096 ^a	0.114 ^a	0.166 ^b	0.013	<0.01
d 0–Final					
DMI, kg/d	10.01	10.41	10.30	0.18	0.18
ADG, kg/d	1.19 ^a	1.58 ^b	1.64 ^c	0.02	<0.01
G:F, kg/kg	0.120 ^a	0.152 ^b	0.160 ^c	0.003	<0.01

^{a-c}Within a row, means without a common superscript differ ($P < 0.05$).

¹Data were analyzed with mortalities (3 digestive) and removals (2 lame) included; final BW for these removals was obtained at time of removal, and average dressing percentage was used to calculate HCW at time of removal.

²Treatments include: 1) Natural—no antibiotics, ionophores, growth implants, or beta-agonists (NAT), 2) Conventional—fed tylosin, monensin, received growth implant, no beta-agonist (CONV), and 3) Conventional w/ zilpaterol—fed tylosin, monensin, received growth implant, fed zilpaterol hydrochloride (87.6 mg/steer last 20 days on feed; CONV-Z).

³Standard error of the mean ($n = 8$). P value is for overall ANOVA.

⁴ADG for CONV vs. CONV-Z tended to differ ($P = 0.08$).

efficiency was not different between CONV and NAT steers during the last 20 d on feed (0.114 vs. 0.096; $P = 0.43$). For overall feedlot performance, CONV-Z steers experienced the greatest ADG, followed by CONV steers then NAT steers having the lowest (1.64 vs. 1.58 vs. 1.19 kg/d, respectively; $P \leq 0.04$). There was no effect of treatment on overall DMI ($P = 0.18$); therefore, CONV-Z steers had the greatest G:F whereas CONV steers were intermediate and NAT steers were the least efficient (0.160 vs. 0.152 vs. 0.120; $P < 0.01$). The addition of technology improved calculated NE_m and NE_g of the diets fed (Table 5). Overall NE_m of the diet was greatest for CONV-Z steers with CONV steers being intermediate and NAT steers the lowest (1.99 vs. 1.93 vs. 1.72 mcg/kg; $P \leq 0.05$), with the same being true for diet NE_g (1.34 vs. 1.29 vs. 1.10 mcg/kg; $P \leq$

Table 5. The effects of treatment on dietary energy calculations¹

Item	Treatment ²			SE ³	P-value ³
	NAT	CONV	CONV-Z		
d 0Z-20Z NE _m , mcal/kg	1.71 ^a	1.83 ^a	2.27 ^b	0.09	<0.01
Overall NE _m , mcal/kg	1.72 ^a	1.93 ^b	1.99 ^c	0.02	<0.01
d 0Z-20Z NE _g , mcal/kg	1.09 ^a	1.19 ^a	1.58 ^b	0.08	<0.01
Overall NE _g , mcal/kg	1.10 ^a	1.29 ^b	1.34 ^c	0.02	<0.01

^{a-c}Within a row, means without a common superscript differ ($P < 0.05$).

¹Calculated according to Zinn (1992). Data were analyzed with mortalities (3 digestive) and removals (2 lame) included; final BW for these removals was obtained at time of removal, and average dressing percentage was used to calculate HCW at time of removal.

²Treatments include: 1) Natural—no antibiotics, ionophores, growth implants, or beta-agonists (NAT), 2) Conventional—fed tylosin, monensin, received growth implant, no beta-agonist (CONV), and 3) Conventional w/ zilpaterol—fed tylosin, monensin, received growth implant, fed zilpaterol hydrochloride (87.6 mg/steer last 20 days on feed; CONV-Z).

³Standard error of the mean ($n = 8$). P value is for overall ANOVA.

0.05). During the last 20 d on feed, the calculated NE_m and NE_g of the diet were the same for NAT and CONV steers (1.71 vs. 1.83 and 1.09 vs. 1.19 mcal/kg; $P = 0.56$); however, CONV-Z steers had a 24% improvement in dietary NE_m and a 32.8% improvement in NE_g compared to CONV steers (2.27 vs. 1.83 and 1.58 vs. 1.18 mcal/kg; $P < 0.01$).

Feedlot Performance: Carcass Basis

Table 6 shows feedlot performance calculated on a carcass basis. On a carcass adjusted basis, ADG and G:F were the greatest for CONV-Z steers, with CONV steers being intermediate and NAT steers the lowest. Carcass adjusted ADG was 6.6% greater for CONV-Z steers compared to CONV steers (1.77 vs. 1.66 kg/d; $P < 0.01$), and 36.1% greater for CONV steers compared to NAT steers (1.66 vs. 1.22 kg/d; $P < 0.01$). Carcass adjusted feed efficiency was 8.1% greater for CONV-Z steers compared to CONV steers (0.172 vs. 0.160; $P < 0.01$) and 31.1% greater for CONV steers compared to NAT steers (0.160 vs. 0.122; $P < 0.01$).

Calculated carcass gain for the entire feeding period was similar to other performance measurements in that CONV-Z steers gained at the fastest rate (1.29 vs. 1.23 vs. 0.95 kg/d; $P \leq 0.03$) and were most efficient with CONV steers being intermediate and NAT steers having the lowest carcass efficiency (0.126 vs. 0.118 vs. 0.095; $P < 0.01$). The improvement in calculated carcass gain for CONV-Z steers was due to a 35.8% improvement in ADG (1.67 vs. 1.23 kg/d; $P < 0.01$) resulting in a 40.2% improvement in efficiency (0.157 vs. 0.112; $P < 0.01$) for CONV-Z steers compared to CONV steers during the 20-d ZH period.

Table 6. The effects of treatment on carcass feedlot performance, mortalities, and removals included¹

Item	Treatment ²			SE ³	P-value ³
	NAT	CONV	CONV-Z		
Carcass adjusted live ⁴					
Final BW, kg	544 ^a	603 ^b	617 ^c	7.58	<0.01
ADG, kg/d	1.22 ^a	1.66 ^b	1.77 ^c	0.03	<0.01
G:F, kg/kg	0.122 ^a	0.160 ^b	0.172 ^c	0.002	<0.01
Carcass gain d 0Z-20Z ⁵					
Pred. d 0Z HCW, kg	329 ^a	357 ^b	356 ^b	4.00	<0.01
Gain, kg	19.68 ^a	28.31 ^b	38.49 ^c	2.69	<0.01
ADG, kg/d	0.86 ^a	1.23 ^b	1.67 ^c	0.12	<0.01
G:F, kg/kg	0.088 ^a	0.112 ^a	0.157 ^b	0.009	<0.01
Carcass gain overall ⁶					
Pred. d 0 dress, %	58.10	58.10	58.09	0.24	0.54
Pred. d 0 HCW, kg	220	220	220	5.58	0.54
ADG, kg/d	0.95 ^a	1.23 ^b	1.29 ^c	0.04	<0.01
G:F, kg/kg	0.095 ^a	0.118 ^b	0.126 ^c	0.004	<0.01

^{a-c}Within row, means without a common superscript differ ($P < 0.05$).

¹Data were analyzed with mortalities (3 digestive) and removals (2 lame) included; final BW for these removals was obtained at time of removal, and average dressing percentage was used to calculate HCW at time of removal.

²Treatments include: 1) Natural—no antibiotics, ionophores, growth implants, or beta-agonists (NAT), 2) Conventional—fed tylosin, monensin, received growth implant, no beta-agonist (CONV), and 3) Conventional w/ zilpaterol—fed tylosin, monensin, received growth implant, fed zilpaterol hydrochloride (87.6 mg/steer last 20 days on feed; CONV-Z).

³Standard error of the mean ($n = 8$). P value is for overall ANOVA.

⁴Carcass adjusted performance data were calculated based on an average dressing percentage of 63.80%.

⁵Predicted HCW is calculated as d 0Z BW $\times$ 0.63. Gain is calculated as (actual HCW – predicted HCW). HCW ADG is calculated as (actual HCW – predicted HCW)/23. The G:F was calculated as HCW ADG/d0Z – d20Z DMI.

⁶Calculated using the equation: Pred. dress = $[0.03 \times (4\% \text{ shrunk initial BW, kg})] + 46.742$. Predicted dress $\times$ initial BW = predicted HCW. ADG and G:F were calculated from the predicted HCW calculation and overall DMI (Parr et al., 2011).

Carcass Characteristics

Table 7 shows the effects of treatment on carcass characteristics. Dressing percentage was greatest for CONV-Z steers (64.68; $P < 0.01$) compared to CONV and NAT steers. However there was no difference in dressing percentage between CONV and NAT steers (63.43 vs. 63.02%; $P = 0.34$). Hot carcass weight was heaviest for CONV-Z steers (394 kg) with CONV steers being intermediate (386 kg) and NAT steers having the lightest HCW (348 kg; $P \leq 0.05$). The CONV cattle had greater FT compared to CONV-Z cattle (1.22 vs. 1.10 cm; $P = 0.03$). There was a trend for an increase in FT between CONV and NAT steers (1.22 vs. 1.12 cm; $P = 0.09$); however, there was no difference in FT between CONV-Z and NAT steers (1.10 vs. 1.12 cm; $P = 0.81$). Longissimus muscle area was increased by 3.6 cm² for CONV-Z steers compared to CONV steers (92.29 vs. 88.67 cm²; $P = 0.02$).

Table 7. The effects of treatment on carcass characteristics

Item	Treatment ¹			SE ²	P-value ²
	NAT	CONV	CONV-Z		
Pens	8	8	8	—	—
Total head	110	110	109	—	—
HCW, kg	348 ^a	386 ^b	394 ^c	5.07	<0.01
Dressing percentage, %	63.02 ^a	63.43 ^a	64.68 ^b	0.23	<0.01
12th rib fat thickness, cm	1.12 ^{ab}	1.22 ^b	1.10 ^a	0.05	0.03
LM area, cm ²	80.16 ^a	88.67 ^b	92.29 ^c	0.89	<0.01
USDA yield grade	3.04 ^a	2.99 ^a	2.65 ^b	0.08	<0.01
Marbling Score ³	471 ^a	470 ^a	432 ^b	11.47	<0.01
USDA quality grade ⁴					
Premium choice, %	32.97	31.57	23.44	5.99	0.29
Low choice, %	55.45	57.80	52.78	4.80	0.76
Choice or greater, %	90.10 ^a	91.02 ^a	78.47 ^b	5.94	0.03
Select, %	9.90 ^a	9.03 ^a	20.70 ^b	5.74	0.04
USDA Yield Grade (YG)					
USDA YG 1, %	4.67 ^a	5.52 ^a	15.14 ^b	3.94	0.04
USDA YG 2, %	42.86	39.25	52.88	5.29	0.16
USDA YG 3, %	48.61 ^a	52.32 ^a	30.70 ^b	5.25	0.02
USDA YG 4–5, %	3.59	2.56	0.89	2.02	0.47
Liver abscess					
Total abscessed, %	13.62	12.93	16.47	3.68	0.74
Normal, %	86.38	87.07	83.53	3.68	0.74

^{a–c}Within row, means without a common superscript differ ($P < 0.05$).

¹Treatments include: 1) Natural—no antibiotics, ionophores, growth implants, or beta-agonists (NAT), 2) Conventional—fed tylosin, monensin, received growth implant, no beta-agonist (CONV), and 3) Conventional w/ zilpaterol—fed tylosin, monensin, received growth implant, fed zilpaterol hydrochloride (87.6 mg/steer last 20 days on feed; CONV-Z).

²Standard error of the mean ($n = 8$). P value is for overall ANOVA.

³400 = Small00, 500 = Modest00, 600 = Moderate00.

⁴USDA Premium Choice = Modest00–Moderate90. USDA Low Choice = Small00–Small90.

and 12.1 cm² compared to NAT (92.29 vs. 80.16 cm²; $P < 0.01$). Due to the decrease in FT and increase in LM area, USDA YG was lowest for CONV-Z steers (2.65; $P < 0.01$) compared to the other treatments with CONV and NAT steers being similar (2.99 vs. 3.04; $P = 0.76$). Marbling score was reduced for CONV-Z steers compared to CONV and NAT steers (432 vs. 470 vs. 471; $P < 0.01$). However, there was no difference in marbling score between CONV and NAT steers (470 vs. 471; $P = 0.99$). The decrease in marbling score resulted in an 11.7% unit increase in USDA Select grading carcasses for CONV-Z steers compared to CONV steers (20.70 vs. 9.03%; $P < 0.05$). There were no differences in quality grade distributions for CONV vs. NAT steers ($P > 0.05$). There was a 9.6% unit increase in USDA YG 1 carcasses (15.14 vs. 5.52%; $P < 0.05$) and a 21.6% unit decrease in USDA YG 3 carcasses (30.70 vs. 52.32%; $P < 0.05$) for CONV-Z steers compared to CONV steers. There was no difference in USDA YG distribution for CONV steers compared

to NAT steers ($P > 0.05$). There was no effect of treatment on percentage of abscessed livers ($P = 0.74$).

DISCUSSION

This study further confirms the improvement in feedlot performance and carcass cutability with the use of efficiency enhancing technologies. The results of this study are similar to those reported by Maxwell et al. (2014). Similar to the current experiment, Coopriders et al. (2011) noted no difference in DMI for steers receiving technologies to those fed naturally for the entire feeding period. However, it is interesting to note that the CONV and CONV-Z cattle consumed more feed for the last 20 d on feed than the NAT cattle. Perhaps this is due to the large difference in BW at the end of the feeding period. It has been shown that implanted cattle will consume more feed than nonimplanted cattle (Mader, 1994; Sawyer et al., 2003; Wileman et al., 2009).

The improvement in ADG and efficiency for CONV-Z compared to NAT was similar to the results by Maxwell et al. (2014). There was a 37.8% improvement in ADG and a 33.3% improvement in G:F in the current experiment compared to a 28.4% improvement in ADG and a 24.2% improvement in G:F reported by Maxwell et al. (2014). These results are also similar to those reported by Coopriders et al. (2011) where a 33.3% improvement in feed efficiency was noted when cattle were fed conventionally compared to naturally. When examining previously published studies, it would appear that NAT cattle are typically fed past their optimum endpoint thus drastically reducing efficiency at the end of the feeding period. However, most natural programs require the cattle to be fed for at least 120 d (Coopriders et al., 2011). Data from this study and Maxwell et al. (2014) suggest that NAT cattle can be harvested when expressing less finish than previously thought and still contain adequate marbling; thus, feedlot efficiency would be reduced less.

In the current experiment, there was no difference in DMI for CONV-Z cattle compared to CONV during the period in which ZH was fed. This is in contrast to the results reported by Holland et al. (2010) where a 4.4% decrease in DMI was noted when cattle were fed ZH. Montgomery et al. (2009) noted a trend for a 1.9% decrease in feed intake when ZH was fed in beef steers. Moreover, Rathmann et al. (2012) showed a 2% reduction in feed intake during the 20 d in which ZH was fed. McEvers et al. (2014) reported a 2.8% decrease in feed intake for the 20-d ZH period. Typically this decrease in DMI during the period in which ZH is fed does not affect overall DMI for the length of the feeding period. However, other studies have shown no effect of ZH on feed intake (Elam et al., 2009; Parr et al., 2011).

The improvement in performance during the 20 d of ZH feeding compared to controls was similar to previously reported results. Montgomery et al. (2009) showed a 43.5% improvement in ADG and 46.6% improvement in feed efficiency when ZH was fed compared to cattle not fed ZH for 20 d, similar to the 42.8 and 45.6% improvements in ADG and feed efficiency noted in the current study, respectively. Similarly, McEvers et al. (2014) reported a 26.6% improvement in ADG as well as a 30.8% improvement in feed efficiency for ZH compared to no ZH. This drastic improvement in ADG and efficiency translates to a significant improvement over the entire feeding period. A meta-analysis by Duffield et al. (2012) concluded that monensin typically increases ADG by 2.5% and reduces DMI by 3.1%, thus, increasing G:F by 1.3%. Holland et al. (2010) reported a 3.1% improvement in feed efficiency for cattle fed ZH compared to nonfed controls, whereas McEvers et al. (2014) reported a 4.0% improvement, slightly less than the 5.3% improvement in feed efficiency noted in the current study. This is further confirmed by data published by Baxa et al. (2010) and Parr et al. (2011) which noted that β -agonists improve feedlot performance regardless of implant use, suggesting the improvement in performance is additive.

As has been previously established in the literature, ZH is most effective at increasing carcass weight gain, as typically the improvement in HCW exceeds the improvement of live weight due to an increase in dressing percentage. As more cattle begin to be marketed on a carcass basis, it becomes critical to assess performance on a carcass basis. Estimating carcass based performance is difficult because of the inability to measure carcass weight on feeder cattle. Therefore, initial carcass weight must be estimated. However, the calculated carcass performances reported in the current study are similar to those reported by Parr et al. (2011), Rathmann et al. (2012), and Maxwell et al. (2014). Interestingly, the effects of treatment on carcass performance were similar to that observed for live performance in the current study. On a calculated carcass gain basis, CONV-Z steers had a 4.9% greater ADG than CONV steers. This improvement was 6.6% on a live weight carcass adjusted basis and 3.8% different on a live basis. Furthermore, comparing CONV-Z steers to NAT steers, the improvement in calculated carcass gain was 35.8%, 45.1% on a carcass adjusted basis, and 37.8% on a live basis. Due to similarities in DMI, these magnitudes of difference hold true for calculated carcass efficiency as well. Maxwell et al. (2014) reported increases in ADG compared to NAT steers of 28.4, 38.7, and 28.3% on a live, carcass adjusted, and calculated carcass gain basis, respectively. Streeter et al. (2012) reported that the ratio of carcass gain to live gain was 88% for steers, regardless of technology use. Therefore, even though the rates of gain are greatly increased by using technology, the

efficiency in which live weight is transferred to carcass weight doesn't seem to change. Interestingly, with a 30 to 40% improvement in ADG, calculated dietary NE_m is improved by 15.7% and NE_g is improved by 21.8% for CONV-Z compared to NAT and 3.1 and 3.9% for CONV-Z compared to CONV, respectively, over the entire feeding period. This is greater than the 10.7 and 14.9% improvement in dietary NE_m and NE_g reported by Maxwell et al. (2014) when comparing similar treatments. Hutcheson et al. (1997) reported that estrogen implants with or without androgens reduces NE_g requirements by 19%, while an androgen implant reduces requirements by 10%. This data would suggest the implants account for 17.9% improvement in NE_g , and ZH accounted for 3.9% of the 21.8% total improvement.

As previously mentioned, due to the requirements of the packing facility for slaughtering NAT cattle, all the cattle were weighed on d 20Z, and then cattle were weighed before shipment, CONV-Z and CONV cattle on Thursdays and NAT on Fridays. Thus, to minimize fill differences and discrepancies across the treatments, the d 20Z BW was used as final BW for all performance calculations. However, the BW taken at shipment was used for calculation of dressing percentage because, due to the withdrawal period, it was 4 to 6 d from when the d 20Z BW was taken and cattle were harvested. The CONV-Z cattle had a 1.64% unit improvement in dressing percentage compared to NAT cattle and 1.25% unit improvement compared to CONV cattle. Compared to NAT steers, this improvement in dressing percentage is very similar to the 1.58% unit improvement noted by Maxwell et al. (2014) when comparing CONV-Z and NAT steers. The improvement in dressing percentage for CONV-Z compared to CONV steers is similar to the 1.2 and 1.3% unit improvement reported by Holland et al. (2010) and Montgomery et al. (2009), respectively. However, it is less than the 1.7% unit increase noted by McEvers et al. (2014). Due to the slightly smaller improvement in dress for CONV-Z steers compared to CONV steers in this study, the difference in HCW was less than the 15-kg advantage typically expected when feeding ZH (Elam et al., 2009). Nonetheless, there was a 10.2-kg improvement in calculated carcass gain during the period in which ZH was fed. As expected and similar to the results of Maxwell et al. (2014), FT was equal between CONV-Z and NAT, with CONV being slightly fatter than CONV-Z. The effects of ZH on FT have been quite variable. Avendaño-Reyes et al. (2006), Rathmann et al. (2012), and McEvers et al. (2014) have reported decreases in FT when feeding ZH compared to a control, whereas others have reported no effect (Beckett et al., 2009; Montgomery et al., 2009; Holland et al., 2010; Parr et al., 2011). Our results and those of Maxwell et al. (2014) indicate that FT was similar for NAT and CONV-Z cattle fed the same number of days. This indicates that

cattle fed for an all-natural program will reach finish with the same number of days as cattle fed using technologies.

The effect of feeding system on quality grade was similar in the current experiment compared to Maxwell et al. (2014) where marbling score was reduced and there was a 10% unit increase in USDA Select cattle for CONV-Z compared to NAT. Even with the increase in USDA Select carcasses, 78% of the CONV-Z cattle graded USDA Choice or greater in the present study. In contrast to other studies (Platter et al., 2003; Baxa et al., 2010), there were no negative effects on USDA quality grade when cattle were implanted with a combination implant (CONV) compared to NAT, as both treatments had 90% of the cattle grade USDA Choice or greater. Similarly, USDA YG distribution was not affected for CONV compared to NAT. However, similar to Maxwell et al. (2014), there was a shift in USDA YG toward a YG 1 for CONV-Z compared to NAT.

Similar to Coopride et al. (2011), there were no differences noted in the presence of abscessed livers in the current study. However, these results differ to those published by Vogel and Laudert (1994) and Maxwell et al. (2014) who noted a significant increase in abscessed livers for naturally fed cattle compared to conventionally fed cattle due to the absence of tylosin in “natural” diets. Overall occurrence of liver abscesses regardless of treatment was significantly less in the current study than what was reported by Maxwell et al. (2014). However, the animals noted as having liver abscesses in the current study fall within the expected range discussed by Nagaraja and Chengappa (1998) of 12 to 32%.

Capper (2012) determined that 22.4% more land, 17.8% more water, and $1,211 \times 10^3$ more animals would be required to produce 1.0×10^9 kg of beef for cattle raised in a NAT system compared to a CONV system, resulting in a 17.4% increase in the carbon footprint of beef production. Stackhouse et al. (2012) suggested that ionophores and implants reduce the carbon footprint by 7%, and β -agonists reduce it by 9%, for a total reduction of 16% in beef production. These improvements in environmental impact discussed all stem from the increase in production efficiency during confinement noted by the current experiment as well as others. To fully evaluate the environmental impact of different production systems, one would need to consider carbon sequestration, waste management, nitrogen volatilization, as well as other important parameters.

Conclusions

The results of this experiment show the production advantages of producing beef in a conventional manner compared to a natural system using a confined system. Beta-agonists, growth implants, and ionophores

are all valuable technologies that help improve gain and efficiency, with minimal effects on carcass quality. To meet the expected 70% increase in food demand by 2050, it will be imperative that efficiency enhancing technologies continue to be used in beef production.

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