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Effects of beef production system on animal performance and carcass characteristics[1]

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ABSTRACT: The objective of this study was to evaluate conventional (CONV) and natural (NAT) beef production systems from annual pasture through finishing through grazing. Beef steers (n = 180, initial BW = 250 ± 19 kg) were assigned randomly to 2 treatments in the pasture phase. Steers were implanted with 40 mg of trenbolone acetate (TBA), 8 mg estradiol, and 29 mg tylosin tartrate (CONV), or received no implant (NAT). Steers on the 2 treatments grazed wheat or cereal rye for 109 d. Conventional steers had an 18.5% improvement in ADG (1.22 vs. 1.03 kg/d, P < 0.01) and a heavier final BW (385 vs. 366 kg, P < 0.01) compared with NAT steers. Following the pasture phase, steers (n = 160 steers, 5 steers/pen, 8 pens/treatment) were assigned to a 2 × 2 factorial in the feedlot phase. Production system (NAT vs. CONV) was maintained from the pasture phase, and the second factor was 7 vs. 12% low-quality roughage (DM basis, LOW vs. HIGH). During finishing, CONV steers were given 120 mg of TBA and 24 mg estradiol at processing, fed monensin and tylosin, and fed zilpaterol hydrochloride for the last 20 d of the experiment. There were no program × roughage level interactions (P > 0.07). The CONV steers ate 6.9% more feed (11.8 vs. 11.0 kg/d, P < 0.01), gained 28.4% faster (1.90 vs. 1.48 kg/d, P < 0.01), and were 24.2% more efficient (0.164 vs. 0.132, P < 0.01) compared with NAT steers. The LOW steers had greater G:F (0.153 vs. 0.144, P < 0.01) compared with HIGH steers. There was a 28.3% improvement in estimated carcass weight gain (1.36 vs. 1.06 kg/d), 18.6% improvement in carcass efficiency (0.115 vs. 0.097, P < 0.01), and 21.6% improvement (1.52 vs. 1.25 Mcal/kg, P < 0.01) in calculated dietary NE_g for CONV compared with NAT steers. Hot carcass weight was increased by 62 kg (424 vs. 362 kg, P < 0.01) and LM area was increased by 16.9 cm^2 (100.9 vs. 84.0 cm^2, P < 0.01), decreasing USDA yield grade (YG, 3.09 vs. 3.54, P < 0.01) for CONV steers compared with NAT steers. Natural steers had a greater percentage of carcasses in the upper 2/3 of USDA Choice grade (48.7 vs. 18.7%, P < 0.01), a greater percentage of YG 4 and 5 carcasses (25.4 vs. 9.3%, P < 0.01), and a greater percentage of abscessed livers (39.6 vs. 10.5%, P < 0.01) compared with CONV steers. The results show that CONV production results in more rapid and efficient production that resulted in heavier carcasses with superior YG and desirable quality grades with both roughage levels.

Key words: beef cattle, conventional, feedlot, growth enhancing technologies, natural

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INTRODUCTION

Due to a substantial increase in the human population, food requirements are expected to increase up to 70% (FAO, 2013) by 2050. The beef industry can play a pivotal role in helping meet the need for increased quantity of food. In recent years, alternatives to CONV beef production have increased in market share, and many consumers perceive benefits of consuming beef products from cattle produced in organic, grass-finished, or antibiotic and growth promotant free systems. The literature database pertaining to a comparison of beef production systems is limited (Fernandez and Woodward, 1999; Woodward and Fernandez, 1999; Wileman et al., 2009; Cooprider et al., 2011; Capper, 2012). Capper (2012) compared CONV, NAT, and grass-fed systems by using an environmental impact model using data from existing databases. Wileman et al. (2009) conducted a meta-analysis to provide a foundation for

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the advantages producers can gain by using modern technologies. In the two-series papers by Fernandez and Woodward (1999), they examined the effects of CONV and organic production practices with a small number of animals. Except for one, all the previously published literature has taken a retrospective view based on several lots of cattle from different locations, breeds, and management, whereas Cooprider et al. (2011) completed a study examining the effects of CONV vs. NAT feedlot practices. Additionally, a common industry practice is to increase roughage level for cattle fed naturally to alleviate digestive disorders and liver abscesses. Impacts of increased roughage on DMI and G:F for naturally fed cattle make comparing the production system complex. Therefore, the study outlined below was designed to fully evaluate the effects of NAT and CONV beef production systems with differing roughage levels on animal performance and carcass characteristics during an annual pasture phase and feedlot finishing phase.

MATERIALS AND METHODS

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

Cattle Management—Pasture Phase

During November 2011, 180 black-hided yearling steers (250 ± 19 kg) from the Chain Ranch in western Oklahoma were utilized for the experiment. The genetic makeup of these steers consisted of primarily Angus and Red Angus genetics. These steers originated from 4 different sites within the Chain Ranch (Ranch 1, 7 steers; Ranch 2, 67 steers; Ranch 3, 93 steers; and Ranch 4, 13 steers). These steers were managed from birth to weaning such that the animals would qualify for an all-NAT program. The steers had received no-implants or antibiotics before initiation of the experiment. The steers were subject to the normal vaccination program of the ranch. At the initiation of the experiment on 2 separate dates (November 8, 2011, $n = 68$; November 15, 2011, $n = 112$), steers were withheld from feed and water overnight. The next morning, steers were individually weighed to the nearest 0.454 kg on validated Tru-Test (Tru-Test, Mineral Wells, TX) scales. An individual electronic identification was given to each animal. Hide brand was recorded to determine ranch of origin. After obtaining the initial BW, steers were stratified by ranch of origin and allocated randomly to one of 2 treatments for the annual pasture phase of the experiment. Cattle received either an implant containing 40 mg trenbolone acetate (**TBA**), 8 mg estradiol and 29 mg tylosin tartrate (**CONV**; Component TE-G, Elanco Animal Health, Greenfield, IN) or no implant (**NAT**). Animals were allowed to graze for 109 d at 2 locations, with each treatment equally represented within location. Location 1 was a 121 ha pasture planted to hard red winter wheat (*Triticum aestivum* 'Duster') containing 112 steers (0.93 steers/ha). Location 2 was a 93 ha pasture planted with cereal rye (*Secale cereal*; 'Elbon') containing 68 steers (0.73 steers/ha). Forage samples were obtained on December 1, 2011 and March 1, 2012 to determine forage available for grazing. Six samples were obtained per collection from Location 1, and 5 samples were obtained from Location 2 by hand-clipping forage to ground level within a randomly placed 0.19 m^2 quadrant. Samples were dried at 55°C to constant weights and used to calculate kilograms of DM/hectare.

On February 28, 2012 and March 5, 2012, cattle from Locations 1 and 2, respectively, were gathered and immediately transported (142 km) to the Willard Sparks Beef Research Center, Stillwater, OK. Upon arrival steers were weighed, ears scored for abnormalities and presence of an implant, and calves sorted into CONV and NAT groups and penned separately. The BW obtained on arrival was used as the final BW of the annual pasture phase. Steers were held in respective groups and fed approximately 2% BW (DM Basis) of a wet-corn gluten based complete feed without monensin (RAMP; Cargill, Inc., Minneapolis, MN) until initiation of the finishing phase.

Cattle Management—Finishing Phase

On March 6, 2012, estimates of 12th–rib fat thickness (**FT**), LM area, and percentage intramuscular fat (**IMF**) of each animal were obtained by ultrasound. On March 12, 2012, all steers were weighed before morning feeding to determine finishing phase allocation weight. From the original 180 steers, 160 steers were chosen for the finishing phase. The steers were culled based on BW or other issues noted (e.g., lameness, poor performance). Steers were reweighed and allocated to treatment the following day. Treatments were arranged in a 2 × 2 factorial randomized complete block design and included production system (CONV or NAT) and diet roughage level (7% [**LOW**] or 12% [**HIGH**], DM basis). Within a production system, steers were blocked by BW, and carcass ultrasound data was used to stratify the animals within production system across roughage level to ensure equal body composition at initiation of the experiment. Steers were sorted into study pens (2 blocks; 4 replications/block; 8 pens/treatment; 5 steers/pen; 40 steers/treatment). On finishing d 0, all steers were vaccinated against clostridial toxins (Caliber 7; Boehringer Ingelheim, St. Joseph, MO), IBR, PI3, BRSV, and BVD types I and II (Express 5; Boehringer Ingelheim), and treated for internal and external parasites (Ivomec Plus; Merial Animal Health, Duluth, GA).

Steers within CONV were administered 120 mg TBA, 24 mg estradiol and 29 mg tylosin tartrate (Component TE-S w/Tylan, Elanco Animal Health; Greenfield, IN). Steers were housed in 4.57 by 15.24 m partially covered feedlot pens. Pens contained a 4.57 × 4.42 m covered concrete pad, with the remainder of the pen being soil-surfaced. Cattle were weighed on d 70, 112, and 135 before morning feeding. Carcass ultrasound was performed at d 70 and used to project common body composition endpoints for each treatment within a block. On d 135, all cattle were weighed at 0000 h. This BW was used as final live BW. A 4% calculated shrink was applied to all BW for calculation of finishing performance. All CONV cattle were shipped 108 km to Creekstone Farms, Arkansas City, KS, for slaughter. The NAT cattle were shipped on d 136 to Creekstone Farms for slaughter. This difference in ship date was due to the requirements of the packing facility in that they only slaughter NAT cattle on Fridays of each week. Chill time differed between treatments with CONV cattle slaughtered on Thursday and graded on the following Tuesday (120 h), whereas the NAT cattle were slaughtered on Friday and graded on Monday (72 h). Carcass data were collected by trained Creekstone personnel using an E + V Vision Grading camera (VBG2000, E + V Technology; Oranienbury, Germany). Liver evaluation was conducted by recording the size and number of abscesses present (Brown et al., 1975). Liver scores O, A, and A+ were utilized as described by Brown and Lawrence (2010).

Feed and Bunk Management

Diet formulations and analyzed nutrient composition are shown in Table 1. All diets were formulated to meet or exceed NRC (2000) requirements. Formulations were targeted to be similar between CONV and NAT within each roughage level. Diets were formulated to contain adequate NPN to meet degradable intake protein requirements (NRC, 2000). The vitamin and mineral supplements were common across diets, except for monensin and tylosin inclusion. The supplement fed in NAT diets contained no monensin or tylosin, whereas those fed in CONV diets were formulated to contain 33 and 9 mg/kg for monensin and tylosin, respectively. For all diets, 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. 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 half of the Bovamine dose with 2.26 kg ground corn in a Kitchen-Aid mixer (Hangzhou Mixer Food Machinery Co., Hangzhou, Zhejiang, China) 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 both the morning and afternoon feeding. Beginning on d 112, CONV steers were fed zilpaterol hydrochloride (**ZH**; Zilmax; Merck Animal Health, DeSoto, KS) at 90 mg·steer^{-1}·d^{-1} for 20 d followed by a 3 d ZH withdrawal period.

This experiment was conducted during a regional drought, with limited availability of quality hay and hay in general. The low-quality mature switchgrass hay used in this experiment was obtained from the Department of Biological Engineering at Oklahoma State University, where it was produced as a fuel source for a cellulosic

Table 1. Ingredient and analyzed nutrient composition of experimental diets

	Experimental diet[1]			
	NAT		CONV	
Diet composition	LOW	HIGH	LOW	HIGH
Ingredient, % DM basis				
Dry-rolled corn	47.91	42.90	47.90	42.89
Ground switchgrass hay[2]	7.04	12.06	7.04	12.06
Dried distillers grains	14.75	14.75	14.75	14.75
Wet-corn gluten feed[3]	14.76	14.76	14.76	14.76
Liquid supplement[4]	10.43	10.42	10.43	10.42
Dry supplement, B-272[5]	5.12	5.11	–	–
Dry supplement, B-273[6]	–	–	5.12	5.12
Nutrient composition[7]				
DM, %	80.95	80.82	80.95	80.82
CP, %	18.10	17.10	17.80	17.10
NPN, %	2.65	2.65	2.80	2.75
ADF, %	11.05	14.00	11.45	13.45
NDF, %	23.90	29.60	24.20	27.85
Fat, %	6.00	5.80	6.35	6.15
Ca, %	0.60	0.58	0.62	0.65
P, %	0.57	0.56	0.57	0.55
Mg, %	0.24	0.25	0.24	0.24
K, %	0.93	0.92	0.92	0.90
S, %	0.32	0.31	0.32	0.31
Monensin, g/t	–	–	33.00	33.00
Tylosin g/t	–	–	9.00	9.00

[1]Natural (NAT) vs. conventional (CONV), and 7% (LOW) and 12% (HIGH) dietary DM roughage inclusion level.

[2]Assayed to contain 1.6% crude protein and 89.5% NDF.

[3]Sweet Bran; Cargill, Inc., Minneapolis, MN.

[4]Synergy 19–14; Westway Feeds, Catoosa, OK.

[5]Formulated 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% $ZnSO_4$, 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.

[6]Formulated 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% $ZnSO_4$, 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.

[7]All values except for DM are on a 100% DM basis. Nutrient composition 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. Monensin and tylosin values are formulated values.

ethanol production project. The hay was hauled to the Willard Sparks Beef Research Center, and ground through a 10.16 cm screen using a HayBuster 1000 grinder (Haybuster Agricultural Products, Jamestown, ND).

Cattle were adapted to assigned finishing diets during a 22 d period. During this phase, CONV steers were fed a portion of RAMP with monensin and their treatment diet, and the NAT steers were fed RAMP without monensin and their treatment diet. Dietary adaptation was accomplished using a two-ration blend method. Each day, treatment diet was increased by 4.6% DM and receiving diet (RAMP with or without monensin) was decreased by 4.6% DM until steers were adapted to the finishing diet. Following adaption, steers were fed twice daily at 0700 h and 1300 h. Feed was mixed and delivered in an 84-8 Roto-Mix mixer wagon (Roto-Mix, Dodge City, KS) and delivered to each pen with delivery accuracy to the nearest 0.454 kg. For the entire study, feeding order remained constant; all NAT pens were fed followed by CONV with a flush batch containing no feed additives to prevent monensin, tylosin, and zilpaterol carryover. Feed bunks were managed to contain trace amounts of feed before the morning feeding, and bunks were cleaned before each feeding to remove items such as manure and hair. A seventy-six-liter concrete water tank (Model J 360-F, Johnson Concrete, Hastings, NE) was shared between each adjacent pen and was cleaned three times weekly throughout the 135-d finishing phase.

Ration samples were collected once per week, dried in a forced air oven for 48 h at 60°C to determine percentage DM. Average DM was calculated for the feeding period and actual DMI was calculated at the end of the study by dividing total pounds of feed consumed by total head days of a pen. Diet samples were composited gravimetrically and analyzed at a commercial laboratory (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. A DM weight was obtained and subtracted from total feed delivered for an accurate DMI calculation.

Performance Calculations

Diet DM formulation was calculated by adjusting the as-fed formulation by the average weekly ingredient DM determined. Overall feedlot performance was calculated, including all mortalities and cattle removed from the experiment. A BW was obtained at time of removal and death, and a dressing percentage was estimated using the equation described by Parr et al. (2011; Predicted dress = [0.03 × 4% shrunk BW, kg] + 46.742) to calculate HCW. Carcass adjusted feedlot performance was calculated using the average dressing percentage of all cattle of 63.90%. Carcass gain and efficiency were calculated for both the entire finishing period, as well as separately for when ZH was fed. Carcass performance for the entire feeding period was calculated using the equation from Parr et al. (2011) to predict initial dressing percentage and HCW. For carcass performance during the ZH period, a dressing percentage of 63% was assumed for all cattle to estimated initial carcass weight. Dietary NE_m and NE_g calculations were performed by using the standard reference weight of 478 kg for animals finishing with small marbling (NRC, 2000). Energy expended for maintenance and retained energy were calculated based on actual performance and DMI using NRC (2000) calculations. The dietary NE_m and NE_g values were then solved using the equation described by Zinn (1992).

Statistical Analysis

All animal performance data were analyzed using PROC MIXED (SAS 9.3; SAS Inst. Cary, NC). For the pasture phase, animal was considered the experimental unit, with source ranch and pasture included as a random effect. For the feedlot phase, pen was considered the experimental unit, and weight block was included as a random effect. Initial BW was used as a covariate when ($P <$ 0.05). All carcass data were analyzed with pen as an experimental unit, and weight block was 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. Cary, NC). All production system × roughage level interactions were considered significant, and means were separated using Tukey's adjustment method when overall ANOVA was significant ($P < 0.05$).

RESULTS

Forage Availability

Initial forage availability was 1127 and 1725 kg/steer for Locations 1 and 2, respectively. Final forage availability was 1106 and 2178 kg per steer for Locations 1 and 2, respectively. Forage allowance was greater in Location 2 than Location 1 throughout the grazing phase. Initial forage available per 100 kg of BW was 419 and 746 for Locations 1 and 2, respectively. Final forage available per 100 kg of BW was 287 and 597 for Locations 1 and 2, respectively. This was mostly due to the lower stocking rate for Location 2 compared with Location 1, and more forage DM/ha in Location 2. Fieser et al. (2007) reported that optimum ADG for steers grazing winter annuals occurred with an average forage allowance of approximately 700 kg of forage DM/100 kg of BW. The forage allowance in this study was near the reported optimum value for Location 2, and below the optimum for Location 1. However, overall steer performance was not different (1.12 vs. 1.14 kg/d; $P = 0.52$) between locations, suggesting forage availability was not a limiting factor.

Feedlot Diet Analyses

Diet DM formulations fed throughout the study are representative of finishing diets fed throughout the industry. Analyzed nutrient composition of the diets fed would indicate that the goals of the formulation were met. Crude protein was in excess of requirements for both diets, due to the high inclusion of corn byproducts.

Monensin assays were completed on composited samples; no monensin was detected in NAT rations (value < 0.9 mg/kg). Monensin values reported for CONV diets were 23.31 mg/kg DM. This is considerably less than formulated values of 33 mg/kg. However, assayed values of the supplement included in CONV diets were 88% of formulated values (511.11 vs. 582.20 mg/kg; DM basis), which is within acceptable limits of assay. Even based on the low assayed value and average DMI throughout the study, the CONV cattle consumed 302 mg·steer^{-1}·d^{-1} monensin, a common industry dosage. The low values reported in CONV diet samples are most likely due to sampling, grinding, and compositing of samples at the end of the experiment. Tylosin was not assayed in these diets.

Zilpaterol hydrochloride was assayed from the composited weekly samples during the period in which ZH was fed. The assayed value (90% DM, basis) for CONV-LOW was 6.52 and 5.71 mg/kg for CONV-HIGH, both within the 75 to 115% permissible assay value. The difference between the two assayed values is potentially due to the roughage level in the HIGH diets. Due to the poor quality of the roughage fed, it was difficult to get a representative composite during grinding and compositing of samples. Based on actual DMI during the ZH period, ZH intake was 92.9 and 84.63 mg·steer^{-1}·d^{-1} for CONV-LOW and CONV-HIGH, respectively, similar to the labeled dose of 70 to 90 mg·steer^{-1}·d^{-1}.

Table 2. The effects of treatment (TRT) on cattle performance while on pasture[1] 0 Ultrasound Data

	Treatment[2]			*P*-value
Item	NAT	CONV	SE[3]	TRT
n	90	90	–	–
Days on pasture	109	109	–	–
Initial BW,[4] kg	250	250	19.13	0.97
Final BW,[4] kg	366	385	11.98	<0.01
ADG, kg/d	1.03	1.22	0.03	<0.01

[1]Data were analyzed with mortalities (4-CONV; 2-NAT).

[2]Treatment examines the comparison of natural (NAT) vs. conventional (CONV).

[3]Standard error of the mean ($n = 90$).

[4]Cattle were withheld from feed and water 12 h before weighing.

Cattle Performance on Pasture

Cattle performance during the pasture phase is shown in Table 2. Initial BW of steers was not different ($P = 0.97$) between CONV and NAT. Conventional steers gained 0.19 kg/d more than NAT steers ($P < 0.01$), resulting in a 19 kg greater ($P < 0.01$) final BW at the end of the 109 d grazing phase. Carcass ultrasound measurements obtained at the end of grazing showed that CONV cattle had 0.06 cm less ($P < 0.01$) FT and contained 0.27% units less ($P < 0.01$) IMF (Table 3). Conventional steers tended ($P = 0.09$) to have a 1.55 cm^2 larger LM area; however, CONV had a lower ($P = 0.04$) LM area/BW ratio compared with NAT.

Table 3. The effects of treatment on initial and d 70 feedlot carcass ultrasound measurements 70 Data

	Production program[1]				Roughage level[2]			
Item	NAT	CONV	SE[3]	*P*-value	LOW	HIGH	SE[3]	*P*-value
d 0								
12th-rib fat thickness, cm	0.47	0.41	0.03	<0.01	0.43	0.45	0.03	<0.01
LM area, cm^2	66.60	68.15	2.01	0.09	67.49	67.25	2.01	0.79
LM area/BW ratio[4]	1.26	1.22	0.04	0.04	1.24	1.23	0.04	0.60
IMF,[6] %	3.86	3.59	0.07	<0.01	3.73	3.72	0.07	0.63
d 70								
12th–rib fat thickness, cm	0.89	0.91	0.03	0.38	0.92	0.88	0.03	0.23
LM area, cm^2	82.50	88.57	1.14	<0.01	85.75	85.32	1.14	0.68
LM area/BW ratio[4]	1.16	1.12	0.04	0.02	1.14	1.14	0.04	0.91
IMF,[5] %	4.39	4.11	0.07	<0.01	4.23	4.27	0.07	0.56

[1]Program examines the comparison of natural (NAT) vs. conventional (CONV).

[2]Roughage level examines the comparison of 7% (LOW) and 12% (HIGH) dietary DM roughage inclusion level.

[3]Standard error of the mean ($n = 16$).

[4]LM area/BW ratio were calculated as LM area/(BW/100).

[5]2.0 to 3.9% = Slight 00–90; 4.0–5.5% = Small 00 to 90; 5.6 to 6.9% = Modest 00 to 90; 7.0–8.5% = Moderate 00 to 90.

Table 4. The effects of treatment on feedlot performance[1] Ultrasound Data

	Production program[2]				Roughage level[3]			
Item	NAT	CONV	SE[4]	*P*-value	LOW	HIGH	SE[4]	*P*-value
Pens	16	16	–	–	16	16	–	–
n	80	80	–	–	80	80	–	–
Days on feed	135	135	–	–	135	135	–	–
Initial BW[5], kg	373	394	25.57	<0.01	383	383	25.57	0.78
d 70 BW[5], kg	488	517	3.23	<0.01	503	503	3.10	0.93
d 112 BW[5], kg	535	594	25.28	<0.01	564	564	25.28	0.89
Final BW[5], kg	578	628	5.96	<0.01	607	599	5.96	0.37
d 0 to 69								
DMI, kg/d	10.70	10.96	0.09	0.06	10.81	10.86	0.09	0.66
ADG, kg/d	1.53	1.97	0.03	<0.01	1.76	1.74	0.03	0.77
G:F, kg/kg	0.143	0.180	0.003	<0.01	0.163	0.160	0.002	0.52
d 70 to 111								
DMI, kg/d	12.26	12.43	0.88	0.86	12.11	12.58	0.78	0.03
ADG, kg/d	1.39	1.70	0.04	<0.01	1.56	1.54	0.04	0.69
G:F, kg/kg	0.118	0.133	0.003	<0.01	0.128	0.123	0.002	0.09
d 112 to 135								
DMI, kg/d	11.00	11.86	0.49	<0.01	11.22	11.65	0.49	0.17
ADG, kg/d	1.49	2.06	0.09	<0.01	1.92	1.62	0.09	0.03
G:F, kg/kg	0.135	0.174	0.01	<0.01	0.171	0.138	0.01	< 0.01
d 0 to 135								
DMI, kg/d	11.01	11.77	0.43	0.01	11.28	11.51	0.43	0.13
ADG, kg/d	1.48	1.90	0.03	<0.01	1.73	1.66	0.03	0.09
G:F, kg/kg	0.132	0.164	0.002	<0.01	0.153	0.144	0.002	< 0.01

[1]Data were analyzed with mortalities (4 digestive, 1 other) and removals (3 footrot) included, final BW for these removals was obtained at time of removal and average dressing percentage was used to calculate a HCW at time of removal. Initial BW was used as a covariate when $P < 0.05$.

[2]Program examines the comparison of natural (NAT) vs. conventional (CONV).

[3]Roughage level examines the comparison of 7% (LOW) and 12% (HIGH) dietary DM roughage inclusion level.

[4]Standard error of the mean ($n = 16$).

[5]A calculated shrink of 4% was applied.

Production Program × Roughage Level Interactions

One of the objectives of this experiment was to determine the appropriate roughage level for NAT cattle. Throughout the experiment, there were no production program × roughage level interactions ($P \geq 0.07$) for feedlot performance or carcass characteristics, suggesting that when feeding a low quality roughage such as ground switchgrass hay, NAT cattle can be fed diets containing dry-rolled corn and as low as 7% diet DM roughage, therefore only the main effects of production program and roughage level are presented.

Feedlot Performance—Production Program—Live Basis

Interim and overall feedlot performance is shown in Table 4. Improved previous performance resulted in initial BW being 21 kg greater ($P < 0.01$) for CONV steers compared with NAT steers. Consistently throughout the feeding period, CONV steers gained 21 to 38% faster, resulting in an overall 28.4% increase ($P < 0.01$) in ADG compared with NAT steers. During d 0 to 69, there was a tendency ($P = 0.06$) for CONV steers to consume more feed than NAT steers. There was no difference ($P = 0.86$) in DMI from d 70 to 111. However, overall CONV steers consumed 7.8% more feed during the ZH feeding period from d 112 to 135 ($P < 0.01$) feed than NAT steers, resulting in an increase (6.9%; $P = 0.01$) in DMI for the 135 d feeding period. Conventional steers were 12.7 to 28.7% more efficient throughout the feeding period, resulting in a 24.2% increase ($P < 0.01$) in G:F compared with NAT steers. Due to the increase in performance, CONV steers had a heavier (50 kg; $P < 0.01$) final BW than NAT steers. There was a 10.7% increase ($P < 0.01$) in calculated overall dietary NE_m and a 14.9% increase ($P < 0.01$) in dietary NE_g for CONV steers compared with NAT steers (Table 5).

Feedlot Performance—Roughage Level—Live Basis

Initial BW between LOW and HIGH steers was not different ($P = 0.78$). Within production program, cattle were stratified across roughage level by initial carcass ultrasound measurements. Therefore, d 0 LM area and IMF were similar ($P \geq 0.63$) and fat thickness was different ($P < 0.01$) between LOW and HIGH steers. How-

Table 5. The effects of treatment on calculated dietary energy values[1] 70 Ultrasound Data

	Production program[2]				Roughage level[3]			
Item	NAT	CONV	SE[4]	*P*-value	LOW	HIGH	SE[4]	*P*-value
d 0 to 69 NE_m, mcal/kg	1.87	2.11	0.03	<0.01	2.00	1.98	0.03	0.42
d 70 to 111 NE_m, mcal/kg	1.74	1.85	0.02	<0.01	1.82	1.76	0.02	0.03
d 112 to 135 NE_m, mcal/kg	1.96	2.28	0.09	<0.01	2.26	1.98	0.09	<0.01
Overall NE_m, mcal/kg	1.77	1.96	0.03	<0.01	1.90	1.83	0.03	<0.01
d 0 to 69 NE_g, mcal/kg	1.23	1.44	0.03	<0.01	1.35	1.33	0.03	0.42
d 70 to 111 NE_g, mcal/kg	1.11	1.21	0.02	<0.01	1.19	1.13	0.02	0.03
d 112 to 135 NE_g, mcal/kg	1.31	1.59	0.08	<0.01	1.57	1.33	0.08	<0.01
Overall NE_g, mcal/kg	1.14	1.31	0.02	<0.01	1.26	1.19	0.02	<0.01

[1]Calculated according to Zinn (1992). Data were analyzed with mortalities (4 digestive, 1 other) and removals (3 footrot) included, final BW for these removals were obtained at time of removal and average dressing percentage was used to calculate a HCW at time of removal.

[2]Program examines the comparison of natural (NAT) vs. conventional (CONV).

[3]Roughage level examines the comparison of 7% (LOW) and 12% (HIGH) dietary DM roughage inclusion level.

[4]Standard error of the mean (n = 16).

ever, the biological and economical relevance is in question due to the small difference in FT (0.43 vs. 0.45 cm for LOW and HIGH, respectively).

There were no differences ($P \geq 0.52$) in feedlot performance from d 0 to 69 due to roughage level. Steers fed 12% roughage (HIGH) consumed 3.9% more (P = 0.03) feed for d 70 to 111 compared with LOW steers with no difference in ADG, resulting in a tendency (P = 0.09) for LOW cattle to be more efficient. At the end of the feeding period (d 112 to 135), LOW steers gained more (P = 0.03) and were more efficient ($P < 0.01$) than HIGH steers. Feeding LOW cattle resulted in an overall tendency (P = 0.09) for improved ADG, and a 6.3% improvement ($P < 0.01$) in feed efficiency compared with HIGH steers, regardless of production program. There was no difference (P = 0.37) in final BW due to roughage level. There was a 3.8% improvement in calculated NE_m and a 5.9% improvement in calculated NE_g for LOW steers compared with HIGH steers ($P < 0.01$).

Feedlot Performance—Production Program—Carcass Basis

Feedlot performance calculated on a carcass basis is presented in Table 6. Overall performance was calculated on a carcass adjusted live basis using the average dressing percentage of all cattle of 63.9%. Carcass adjusted ADG was increased ($P < 0.01$) by 38.7% for CONV steers compared with NAT steers, resulting in a 33.1% improvement ($P < 0.01$) in carcass adjusted feed efficiency. Predicted overall carcass gain was calculated using an equation by Parr et al. (2011). Initial dressing percentage was 0.64% units greater ($P < 0.01$) for CONV cattle than NAT cattle. Predicted carcass ADG was increased ($P < 0.01$) by 0.30 kg/d for CONV steers compared with NAT steers, and CONV steers were 18.6% more ($P < 0.01$) efficient on a carcass efficiency basis. Carcass gain calculated during d 112 to 135 when ZH was fed resulted in 0.76 kg/d greater ($P < 0.01$) carcass gain and a 64.0% improvement in carcass efficiency ($P < 0.01$).

Feedlot Performance—Roughage Level—Carcass Basis

On a carcass adjusted basis, LOW steers had greater ($P \leq 0.03$) ADG and G:F compared with HIGH steers. Calculated overall carcass G:F was increased (P = 0.03) by 7.8% for LOW steers compared with HIGH steers regardless of production program.

Carcass Characteristics—Production Program

Carcass characteristics are shown in Table 7. Based on the carcass ultrasound measurements obtained at d 70 there were no differences in FT between CONV and NAT steers or weight blocks (P = 0.38); therefore, it was determined that all cattle should be slaughtered at the same days on feed (DOF), to ensure the cattle within each production program had equal FT, an indicator of carcass composition. Dressing percentage was increased ($P < 0.01$) by 1.58% units, resulting in a 62 kg heavier ($P < 0.01$) HCW for CONV steers compared with NAT steers. Final FT was similar (P = 0.53) for CONV steers and NAT steers. Longissimus muscle area was increased ($P < 0.01$) by 16.94 cm^2 for CONV steers compared with NAT steers; however, there was no difference (P = 0.15) in the ratio of LM area:HCW. Therefore, calculated YG was lower ($P < 0.01$) for CONV steers compared with NAT steers. There was a 19.9% unit increase in YG 2, and a 16.04% unit decrease in YG 4 and 5 for CONV steers compared with NAT steers ($P \leq 0.02$). Marbling score was decreased ($P < 0.01$) for CONV steers compared with NAT steers. There was a tendency (P = 0.06)

Table 6. The effects of treatment on calculated carcass performance[1] 70 Ultrasound Data

	Production program[2]				Roughage level[3]			
Item	NAT	CONV	SE[4]	*P*-value	LOW	HIGH	SE[4]	*P*-value
Carcass adjusted[5]								
Final BW, kg	571	635	7.13	<0.01	610	597	6.85	0.22
ADG, kg/d	1.42	1.97	0.03	<0.01	1.75	1.64	0.03	0.03
G:F, kg/kg	0.127	0.169	0.002	<0.01	0.155	0.142	0.003	<0.01
Carcass gain d 112 to 135[6]								
Pred. HCW, kg	337	374	15.93	<0.01	356	355	15.93	0.89
ADG, kg/d	0.97	1.73	0.08	<0.01	1.52	1.19	0.08	<0.01
G:F, kg/kg	0.089	0.146	0.009	<0.01	0.135	0.101	0.009	<0.01
Carcass gain overall[7]								
Pred. dress, %	57.92	58.56	0.77	<0.01	58.24	58.23	0.77	0.78
Pred. HCW, kg	216	231	17.86	<0.01	224	223	17.86	0.79
ADG, kg/d	1.06	1.36	0.03	<0.01	1.24	1.18	0.03	0.18
G:F, kg/kg	0.097	0.115	0.006	<0.01	0.110	0.102	0.006	0.03

[1]Data were analyzed with mortalities (4 digestive, 1 other) and removals (3 footrot) included, final BW for these removals was obtained at time of removal and average dressing percentage was used to calculate a HCW at time of removal. Initial BW was used as a covariate when $P < 0.05$.

[2]Program examines the comparison of natural (NAT) vs. conventional (CONV).

[3]Roughage level examines the comparison of 7% (LOW) and 12% (HIGH) dietary DM roughage inclusion level.

[4]Standard error of the mean ($n = 16$).

[5]Carcass adjusted performance data were calculated based on an average dressing percentage of 63.90%.

[6]Predicted HCW is calculated as d 112 BW × 0.63. HCW ADG is calculated as (actual HCW-predicted HCW)/23. The G:F was calculated as HCW ADG/ d112 – 135 DMI.

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

for a 12.9% unit decrease in USDA Choice or greater with a shift to USDA Select. Cattle on the CONV treatment had a 29.1% unit decrease ($P = 0.01$) in abscessed livers, with a 15.3% unit decrease ($P = 0.02$) in livers scored A+, and a trend ($P = 0.06$) for a 10.7% unit decrease in livers scored A, compared with NAT steers.

Carcass Characteristics—Roughage Level

There was a 9 kg increase ($P = 0.02$) in HCW for LOW steers compared with HIGH steers, with no other differences in carcass characteristics ($P \geq 0.10$). There were no differences ($P = 0.97$) in total abscessed livers between LOW steers and HIGH steers. However, there was a trend ($P = 0.10$) for an increase in abscess severity for LOW steers compared with HIGH steers for those livers that contained abscesses.

DISCUSSION

The objectives of this study were to evaluate system differences in CONV and NAT cattle systems. Evaluations were conducted from pasture performance through the carcass characteristics and included 2 dietary roughage levels during the finishing phase. Previously, live animal experiments have been completed examining the differences among CONV, NAT, and organic production (Fernandez and Woodward, 1999; Woodward and Fernandez, 1999; Cooprider et al., 2011), and one metaanalysis was completed examining the differences due to growth-enhancing products during the finishing phase (Wileman et al., 2009). The present experiment is the first to use genetically similar animals to examine the differences between CONV and NAT production programs in a manner similar to a commercial setting, beginning at the pasture phase. Cooprider et al. (2011) focused on greenhouse gas emissions and sustainability, and in doing so, used average pen BW as a targeted final constant BW, whereas commercial operations would most typically use FT as a predictor of physiological composition at finish.

The results of the grazing phase were similar to those reported in the literature. The ADG advantage (0.19 kg/d) for CONV during the pasture phase was similar to results reported by McMurphy et al. (2013) and Sharman et al. (2011) for implanted steers grazing similar pastures. The authors reported a 0.10 and 0.13 kg/d advantage, respectively, when administering Component TE-G, with the implant resulting in a 25 kg heavier BW at the end of grazing. Similarly, McMurphy et al. (2011) showed an improvement in ADG of 0.08 kg/d, resulting in a 10 kg heavier BW at the end of a warm-season grazing period when cattle were implanted with Component TE-G compared with no implant. The increase in ADG is greater in the present study compared with the published studies, presumably due to the amount of available forage available with lower stocking rates.

There were improvements in feedlot performance for CONV compared with NAT in the present experiment.

Table 7. The effects of treatment on carcass characteristics

	Production program[1]				Roughage level[2]			
Item	NAT	CONV	SE[3]	*P*-value	LOW	HIGH	SE[3]	*P*-value
n	78	75	–	–	76	77	–	–
Stun weight,[4] kg	566	646	27.49	<0.01	608	604	27.49	0.32
Shrink,[4] %	5.16	5.05	0.42	0.67	5.32	4.89	0.42	0.10
HCW, kg	362	424	16.08	<0.01	398	389	16.08	0.02
Dressing percentage	63.31	64.89	0.21	<0.01	64.37	63.83	0.21	0.08
12th–rib fat thickness, cm	1.74	1.79	0.07	0.53	1.75	1.78	0.07	0.71
LM area, cm^2	83.95	100.89	1.04	<0.01	93.54	91.30	1.04	0.14
LM area/HCW ratio[5]	1.63	1.68	0.07	0.15	1.66	1.65	0.07	0.90
Marbling score[6]	500	421	6.37	<0.01	465	456	6.37	0.33
USDA quality grade[7]								
Premium Choice, %	48.70	18.72	–	<0.01	32.15	31.59	–	0.95
Low Choice, %	36.93	54.05	–	0.05	44.66	46.04	–	0.87
≥ Choice, %	85.95	73.06	–	0.06	80.53	80.04	–	0.94
Select, %	14.05	26.94	–	0.06	19.47	19.96	–	0.94
Avg. USDA YG[8]	3.54	3.09	0.20	<0.01	3.28	3.34	0.20	0.62
USDA YG								
USDA YG 1, %	5.13	5.48	–	0.93	3.73	7.49	–	0.32
USDA YG 2, %	17.58	37.52	–	0.01	27.00	25.73	–	0.97
USDA YG 3, %	48.69	44.56	–	0.62	52.54	40.78	–	0.15
USDA YG 4–5, %	25.36	9.32	–	0.02	13.95	17.73	–	0.66
Liver Abscess								
A +, %	20.03	4.72	–	0.02	14.85	6.64	–	0.18
A, %	16.14	5.4	–	0.06	6.46	13.75	–	0.19
Total abscessed, %	39.56	10.51	–	<0.01	21.84	21.57	–	0.97
A+, % of abscessed	56.35	46.41	–	0.65	69.10	33.33	–	0.10
A, % of abscessed	43.65	53.59	–	0.65	30.90	66.67	–	0.10

[1]Program examines the comparison of natural (NAT) vs. conventional (CONV).

[2]Roughage level examines the comparison of 7% (LOW) and 12% (HIGH) dietary DM roughage inclusion level.

[3]Standard error of the mean ($n = 16$).

[4]Stun weight was obtained immediately after animal was knocked unconscious, and shrink was calculated as [(final BW – stun weight)/final BW] × 100.

[5]LM area/HCW ratio were calculated as LM area/(HCW/100).

[6]400 = Small00, 500 = Modest00, 600 = Moderate00.

[7]USDA Premium Choice = Modest00 to Moderate90. USDA Low Choice = Small00 to Small90.

[8]YG = yield grade.

The current study resulted in a 0.42 kg/d increase in ADG for CONV compared with NAT fed steers. Capper (2012) predicted ADG almost identical to those calculated in the present experiment for CONV and NAT cattle. Cooprider et al. (2011) showed a 0.46 kg/d increase in ADG when steers started the finishing period at the same weight, received 2 implants, and were fed monensin, tylosin, and ractopamine hydrochloride, compared with cattle that had never received any of the technologies. In contrast, steers never receiving any technologies consumed the same amount of feed as those receiving technologies (7.8 vs. 7.6 kg/d; $P = 0.22$; Cooprider et al., 2011). In the present study, CONV steers consumed 0.76 kg/d more feed than NAT; however, CONV steers were heavier due to the grazing implant at the beginning at the feeding phase, potentially increasing intake. Mader (1994) showed a 0.81 kg/d increase in DMI for steers implanted during the growing and finishing periods compared with cattle never implanted. It appears that the suggested 3% decrease in DMI due to the feeding of monensin in the finishing period for the CONV cattle (Duffield et al., 2012) was masked due to the greater starting weight for CONV.

Cooprider et al. (2011) observed a 33.3% improvement in feed efficiency when feeding cattle conventionally compared with naturally. This is greater than the 24.2% improvement in the present study; however, this is potentially due to the additional 42 d the NAT cattle were fed in the Cooprider et al. (2011) study to feed the cattle to the same final BW. In the present study, it is clear that NAT cattle became less efficient as the study progressed, especially on a carcass basis, and thus feeding NAT cattle past their optimum compositional endpoint could decrease efficiency of gain.

Zilpaterol hydrochloride was fed to the CONV cattle in this study due to its advantageous effects on carcass weight and value when marketing cattle on a carcass basis. Parr et al. (2011) examined the effects of anabolic implant in combination with ZH on carcass gain and efficiency at the end of the feeding period. The authors noted no implant by ZH interaction, indicating that these two technologies are additive. Over a 152 d feeding period (Parr et al., 2011), there was a 0.18 kg/d increase in carcass ADG, and a 9.8% improvement in efficiency when using an implant strategy similar to the one used in the current study compared with no implant, and a 0.12 kg/d increase in carcass ADG and a 8.7% improvement in efficiency when feeding ZH for 20 d. If additive, one would expect a 0.30 kg/d increase in carcass ADG and an 18.5% improvement in carcass efficiency (Parr et al., 2011). These results are similar to the current study, in which a 0.30 kg/d improvement in ADG and an 18.6% improvement in efficiency on a predicted carcass basis occurred for CONV cattle compared with NAT over the entire feeding period. Rathmann et al. (2012) examined the effects of ZH on carcass performance in beef heifers. There was a 0.36 kg/d increase in carcass ADG, resulting in a 35.9% increase in carcass efficiency for cattle fed ZH. In the present experiment there was a 0.76 kg/d increase in carcass ADG, and a 65% increase in carcass efficiency over the last 23 d of the feeding period for CONV compared with NAT. Most likely, the large disparity in these data is due to decreased efficiency of the NAT cattle at the end of the feeding period.

Dressing percentage has been consistently increased by approximately 1.5% units when cattle are fed ZH (Montgomery et al., 2009; Holland et al., 2010; Parr et al., 2011; Rathmann et al., 2012). Similar results were observed in this study with a 1.6% unit increase in dressing percentage for CONV vs. NAT. Cooprider et al. (2011) showed no difference in dressing percentage for CONV vs. NAT cattle when ractopamine hydrochloride was fed. Parr et al. (2011) reported no difference in dressing percentage between cattle never implanted vs. cattle implanted with a similar implant to the one used in this experiment. Similarly, Bryant et al. (2010) reported no differences in dressing percentage when cattle were implanted compared with nonimplanted cattle.

The reported increase in dressing percentage due to the feeding of ZH typically results in 13 to 15 kg additional HCW when cattle are fed ZH. In the present experiment, with 2 implants and the feeding of ZH, HCW was increased 62 kg compared with NAT. Cooprider et al. (2011) only reported a 6 kg increase in HCW between NAT and CONV cattle fed ractopamine hydrochloride; however, NAT cattle in that study were fed longer to target a similar final BW rather than compositional end point. Sawyer et al. (2003) reported a 35 kg increase in HCW for cattle implanted twice during the finishing period, compared with no implants, and no difference in HCW for steers being fed monensin and tylosin, compared with those not being fed the two additives. Again, assuming that implants and ZH are additive, Parr et al. (2011) reported a 47 kg increase in HCW with the use of both technologies compared with animals not administered implants or fed zilpaterol, though that study did not include a stocker phase.

As expected, LM area was increased when cattle were fed CONV compared with a NAT program. Bryant et al. (2010) reported no increase in LM area when ractopamine was fed; however, there was an increase in LM area due to implant. Parr et al. (2011) reported an increase in LM area for steers receiving Revalor-S and fed ZH compared with nonimplanted steers not fed ZH. Similarly, Cooprider et al. (2011) reported a large increase in LM area for CONV cattle compared with NAT cattle. As per the current study design, there were no effects of treatment on FT. This was done to ensure commercial applicability of the results of this experiment. Surprisingly, there was no difference between treatments for FT from d 0 (ultrasound) through harvest. Cooprider et al. (2011) noted an increase in FT for NAT cattle compared with CONV cattle when fed to the same weight. Due to the increase in HCW and LM area for CONV steers, there was a significant shift in YG from 3 to 2 compared with NAT. This is similar to other reported data (Cooprider et al., 2011). Bryant et al. (2010) and Parr et al. (2011) noted no decrease in calculated YG or shift in YG distribution for cattle implanted or fed β-agonists. It is noted in the present data that there was a numerical increase in LM area in proportion to HCW for CONV, perhaps resulting in this shift in YG. In addition, even though both groups of cattle carried the same amount of FT, the LM area was much smaller in the NAT cattle, resulting in greater YG. Natural cattle should be marketed with less FT than CONV cattle, offsetting smaller LM area and maintaining desirable YG.

Our data are similar to other published data, suggesting a reduction in marbling score and a slight shift in USDA Quality Grades for cattle receiving technologies compared with those not receiving technologies (Sawyer et al., 2003; Baxa et al., 2010; Bryant et al., 2010; Cooprider et al., 2011). However, Parr et al. (2011) noted no effects of implants or supplementation with ZH on marbling scores. It is interesting to note that high quality cattle were used in this experiment (> 70% grading USDA Choice or better). The shift in USDA Quality Grades for cattle fed with technology was not from Choice to Select. The shift occurred within the Choice grade with fewer CONV carcasses in the upper 2/3 of Choice compared with NAT. This is in contrast to Rathmann et al. (2012) and Montgomery et al. (2009), who reported a 6% unit increase in the number of cattle grading USDA Select when ZH was fed, and Bryant et al. (2010), who reported a 12% unit increase in the number of cattle grading USDA Select when calves received growth implants. However, the animals used in these studies had lower average Quality Grades than those used in the current study.

Contrary to the results of this study, Cooprider et al. (2011) reported no difference in liver abscesses between CONV and NAT cattle where the CONV animals were fed tylosin. Brown and Lawrence (2010) examined the effects of liver abscesses on carcass performance. The results were striking, and perhaps a portion of the decrease in feedlot performance and ultimately carcass characteristics in this experiment stems from the large increase in abscessed livers due to the inability to feed tylosin in most NAT programs (Brown and Lawrence, 2010). Previous research suggest a marked decrease in dressing percentage, HCW, FT, and LM area for cattle exhibiting abnormal livers compared with those with normal livers, resulting in a lower carcass value (Brown and Lawrence, 2010). Vogel and Laudert (1994) reported a 73% reduction in the occurrence of liver abscesses by feeding tylosin, resulting in a 2.3% improvement in ADG and a 2.6% improvement in efficiency.

Over the course of the finishing portion of the experiment, there were 5 animal mortalities: (2 CONV/HIGH, 2 CONV/LOW, and 1 NAT/HIGH); and 3 steers removed for lameness: (1 CONV/LOW, 1 NAT/LOW, and 1 CONV/HIGH). Of the animals that died, 4 were diagnosed as digestive mortalities and 1 CONV/HIGH was euthanized because of lameness. Due to the low mortality numbers in this experiment, these data could not be statistically analyzed. However, we hypothesize that the genetic propensity of these cattle to perform, coupled with the increased DMI in CONV cattle, could potentially be related to the increased death loss for cattle due to digestive disorders in CONV (3 vs. 1) compared with NAT. Furthermore, these data suggest that feeding NAT cattle similar amounts of roughage as CONV did not increase digestive disorders. Throughout the experiment, the cattle consuming LOW, regardless of production program, tended to consume less feed, gain at a faster rate, and were significantly more efficient than cattle consuming HIGH. It is important to note that the ground switchgrass hay fed in this study was of extremely low quality. Composited assay values suggest CP of 1.6% and NDF of 89.5% for the ground switchgrass hay. In addition, throughout the experiment, the cattle consuming HIGH sorted the larger roughage particles out of the ration. There are no published data pertaining to roughage requirements for NAT cattle. The slight increase in DMI for HIGH compared with LOW is supported by Galyean and Defoor (2003). As NDF in high concentrate diets increase, DMI increases. However, in this experiment, DMI was not increased enough to increase total energy intake, thus ADG was lower for cattle fed HIGH. Perhaps, in this experiment, 7% switchgrass was adequate to promote rumen health even in the NAT cattle not fed monensin. It has been well established throughout the literature that, in feedlot conditions, increasing dietary roughage typically increases feed intake, but typically there is little effect on ADG, resulting in poorer feed efficiency (Calderon-Cortes and Zinn, 1996; Loerch and Fluharty, 1998; Galyean and Defoor, 2003). However, one must remain cognizant about providing enough dietary roughage to minimize the amount of digestive disorders. The results of this study suggest that a lower roughage level can be fed to NAT cattle when the roughage source is low-quality such as the switchgrass in this study. However, more research is needed to verify these findings with other roughage sources, before commercial applicability.

Conclusions

Over the course of the next decade, it will be imperative to continue to explore ways to improve efficiency and productivity of beef production. The results of this study clearly show the advantage in using growth enhancing technologies on performance and carcass characteristics of stocker and feedlot cattle. This study also shows that when feeding a low-quality roughage such as switchgrass, a lower roughage level can be fed to NAT cattle. Based on per capita beef disappearance of carcass weight in 2012 of 37.15 kg, the added 62 kg of HCW for a single CONV steer compared with NAT steer is enough to feed 1.66 more U.S. Citizens per year per animal (USDA–ERS, 2013). As society has increasing concerns over technologies used in animal production, it will be imperative to continue to communicate the benefits of methods to increase animal productivity, reduce environmental impact, and improve animal wellbeing. Further investigation should be explored to determine the effects of growth enhancing technologies used in complete production systems on product acceptability and animal wellbeing so that management decisions can be made to meet the three goals of sustainability as presented by Cooprider et al. (2011): economically advantageous, environmentally friendly, and socially acceptable.

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