# COMPARISON OF TECHNOLOGIES IN BEEF PRODUCTION SYSTEMS

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# COMPARISONS OF TECHNOLOGIES IN BEEF PRODUCTION SYSTEMS

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Abstract: Beef steers (n = 180; initial BW = 250 ± 19 kg) were randomized to one of two treatments in the pasture phase. Steers were implanted with 40 mg of TBA, 8 mg estradiol, and 29 mg tylosin tartrate (Conventional; CONV-Z) or received no implant (Natural; NAT). Conventional steers had improved ADG and a heavier final BW compared with NAT steers. Following the pasture phase, steers were assigned to a 2 × 2 factorial in the feedlot phase. Production system (NAT vs. CONV-Z) was maintained from the pasture phase, and the second factor was 7 vs. 12% roughage (DM basis; LOW vs. HIGH). Conventional steers ate more feed, gained faster and were more efficient compared with NAT steers. Hot carcass weight and LM area was increased for CONV-Z steers compared with NAT steers. Conventional steaks had increased slice shear values and Warner-Bratzler shear force compared with NAT steaks. Steaks from cattle fed CONV-Z had higher moisture content, lower lipid content, higher protein and higher ash content than steaks from NAT cattle. In experiment 2, steers (n = 336; initial BW = 379 ± 8 kg) were randomized to similar treatments. CONV-Z steers gained faster and were more efficient than CONV steers, and CONV steers gained faster and were more efficient than NAT steers. Hot-carcass weight was increased for CONV-Z steers compared to CONV steers and compared to NAT steers. In experiment 3, beef steers (n = 54; initial BW = 391 ± 3 kg) were randomized to one of two treatments, an all-natural treatment (NAT), and a conventional treatment (CONV-Z). Gain and feed efficiency was improved for CONV-Z steers compared to NAT steers. Daily water intake was numerically greater for NAT steers compared to CONV-Z steers and total feed and water efficiency was improved by 50% for CONV-Z steers compared to NAT steers. Natural steers spent more time at the feed and water bunk than CONV-Z steers. Hot-carcass weight and LM area were increased for CONV-Z compared to NAT steers. Data from these experiments show that conventional production increases animal performance and net return without drastically affecting meat quality.

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# CHAPTER I

## INTRODUCTION

Since the early 1950s efficiency enhancing technologies have been widely used in the beef industry with the first being diethylstilbestrol (Raun and Preston, 2002). Most recently, 2 new commercially available beta adrenergic agonists (**BAA**) were introduced in North America in the 2000s (Johnson et al., 2013). With the introduction of these technologies, management practices have been implemented to effectively use antimicrobials, ionophores, growth implants and BAA for increasing beef cattle production. These technologies have played a pivotal role in improving beef production efficiency and helping provide a safe, affordable protein source for feeding the worlds growing population. Coupled with other improvements, technology use has reduced animal number requirements by 69.9%, and land use by 67% to produce the same amount of beef in 2007 as in 1977 (Capper, 2011). Moreover in the same time period, average beef yield per animal has increased 77 kg per animal from 274 kg to 351 kg (Capper, 2011). These technologies have also played a pivotal role in helping mediate beef prices due to lower production costs. Data have shown a $77/animal lower cost of production for implanted cattle compared to non-implanted cattle, and a $349/animal lower cost of production compared to organically raised cattle (Wileman et al., 2009). Duckett et al. (2013) calculated that if two combination implants (estrogen + trenbolone acetate) were used a net return of $219/steer would be realized compared to non-implanted controls. Cooprider et al. (2011) reported a $0.23/kg of BW gain reduction for cattle produced conventionally using technologies (implants and BAA) compared to cattle produced naturally (without the use of technologies).

Even with the improvement in animal performance and improved economic efficiency, the use of technology has been under scrutiny from various groups due to concerns over animal welfare, decreased retail meat quality and overall sustainability of beef production. Also, some producers have modified production practices to target niche markets that promote no technology use because they believe these products are superior or because of perceived increased price premiums. Capper (2012) defined sustainability as "meeting society's present needs without compromising the ability of future generations to meet their own needs." This definition shows that beef production must be accomplished by providing a safe, wholesome, affordable product to consumers, but must also allow producers to meet their own needs by being economically efficient. Therefore, technology must play a pivotal role in the sustainability of beef production.

Technology use in beef production has many components. The objectives of the experiments presented in this document were to: 1) Evaluate the effects of technology use in beef production systems on animal performance, carcass characteristics, and feed and water intake behavior ; 2) Evaluate the effects of technology use on retail meat attributes and human health implications; 3) Evaluate the economic viability of technology use in beef production systems; and 4) Expand the current knowledge regarding the use of technologies on animal performance, retail meat attributes and economic viability that can be further used to improve the sustainability of beef production.

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# CHAPTER II

# REVIEW OF LITERATURE

## TECHNOLOGY USE

### *History of Technology Use*

As previously mentioned, oral diethylstilbestrol was approved by the FDA in 1954, whereas zeranol implants were approved in 1969 and estradiol/trenbolone acetate combination implants were approved in 1991 (Johnson et al., 2013). Monensin (Rumensin, Elanco Animal Health; Greenfield, IN) an ionophore commonly used for increased feed efficiency was approved in the mid 1970's (Duffield et al., 2012) and tylosin has been used since the early 1960's (Johnson et al., 2013). The most recent growth promotant was approved in 2006 (zilpaterol hydrochloride, Zilmax; Merck Animal Health, DeSoto, KS).

### *Adoption of Technologies*

The use of efficiency enhancing technology in beef production is widely adopted. Commonly used technologies are growth-promoting implants, ionophores, antimicrobials, and beta-adrenergic agonists (**BAA**). According to the USDA National Animal Health Monitoring System (NAHMS) Feedlot study in 2011, 90.4% of all feedlot steers weighing less than 318 kg were given at least 1 growth-promoting implant, whereas, 84.3% of all steers weighing greater than 318 kg were given a growth promoting implant. Of the cattle weighing less than 318 kg, 62.7% of those steers were given at least 2 growth-promoting implants while on feed. Moreover, 90.5% of all feedlots surveyed used an ionophore, 47.5% fed a BAA (36.9% fed

Optaflexx, Elanco Animal Health, 10.6% fed Zilmax, Merck Animal Health). Of the feedlots surveyed, 73.8% of all cattle less than 318 kg were fed tylosin (Tylan, Elanco Animal Health) for the control of liver abscesses (NAHMS, 2011). This data would indicate that the adoption rates of technologies are quite high. However as mentioned in the introduction, some outside public pressure and concern is provoking question about the use of efficiency enhancing products.

## GROWTH-PROMOTING IMPLANTS

### *Mode of Action*

There are 3 commonly used types of steroidal growth-promoting implants: estrogens, androgens and progestins (Johnson et al., 2013). Steroids can either be naturally occurring (estrogen (**E**), testosterone and progesterone) or synthetic (zeranol, trenbolone acetate (**TBA**), melengesterol acetate; Johnson et al., 2013). Growth-implants are typically composed of estrogens and androgens, whereas the progestins are commonly used to suppress estrus in feedlot heifers; however there are a few growth-promoting implants containing progesterone. Duckett and Pratt (2014) published a list of the 33 currently FDA approved implants. Implants increase protein concentrations by increasing production of insulin-like growth factor I (**IGF-I**; Johnson et al., 2013) and growth hormone (**GH**) through binding of cytosolic receptors (Bryant et al., 2010). The increase in IGF-I and GH stimulates skeletal muscle hypertrophy by increasing protein synthesis, and decreasing protein degradation. The most commonly used implants are the TBA/E combination implants. Bryant et al. (2010) discussed that androgens such as TBA act directly on the muscle, whereas estrogens affect the hypothalamus and anterior pituitary to increase GH secretion. Muscle fiber number is fixed at birth, and muscle growth only occurs via an increase in muscle size (hypertrophy). For muscle growth to occur, muscle DNA must be produced and since muscle cells cannot divide, satellite cells must produce the DNA for muscle cells to increase in size (Johnson et al., 1998). Johnson et al. (1998) discovered that Revalor-S (Merck Animal

Health), a TBA/E combination implant, increases muscle satellite cell growth, which increases muscle growth.

### *Effects on animal performance and carcass characteristics*

Growth-promoting implants have been shown to be very effective in increasing gain and efficiency in beef production. During grazing programs prior to finishing, a single combination implant has been shown to increase ADG by 0.10 to 0.13 kg/d, resulting in an additional 25 kg of BW (Sharman et al., 2012; McMurphy et al., 2013). Reuter and Beck (2013) reviewed the effects of stocker implants on feedlot performance. Results are variable in how implants administered during the stocker phase affect feedlot performance. However, results would indicate the added weight gain obtained during the stocker phase is not lost during finishing (Duckett and Andrae, 2001; Platter et al., 2003; Barham et al., 2012).

Duckett and Pratt (2014) summarized the effects of implants on ADG and efficiency from several studies during the finishing phase. A single estrogen implant has been shown to improve ADG and improve feed efficiency by 16.4 and 6.2%, respectively. A single combination implant has been shown to improve ADG and reduce feed:gain by 19.1 and 10.4%, respectively (Duckett and Pratt, 2014). The use of a combination implant followed by reimplantation of another combination implant resulted in a 20.0 and 13.5% improvement in ADG and decrease in feed:gain, respectively (Duckett and Pratt, 2014). Johnson et al. (1996) reported a 15.6% improvement in ADG with a 5-13% improvement in efficiency depending upon the period in which it was measured, for a single combination implant compared to non-implanted controls. There was no effect of implant on dry-matter intake. Implantation increased total carcass protein, water, and bone but had no effect on carcass fat throughout the feeding period. Parr et al. (2011) noted a 19.9% increase in ADG and a 12.4% improvement in efficiency for Revalor-S (120 mg TBA and 24 mg E) compared to a non-implanted control. However when animals were implanted with Revalor –XS (200 mg TBA and 40 mg E), there was no added advantage in ADG, however feed efficiency was improved by 4.7% compared to the Revalor-S cattle. The effects on

DMI due to growth implants is quite variable. Mader et al. (1994) showed a 0.81 kg/d increase in DMI for cattle implanted compared to non-implanted controls. However, Parr et al. (2011) showed no increase in DMI when steers were implanted with Revalor-S or Revalor-XS compared to a non-implanted control. Data clearly elucidates the benefits of growth-promoting implants on feedlot performance. However, there is some concern over the effects of implants on carcass quality.

Platter et al. (2003) noted a 108 point increase in marbling score for animals never implanted compared to animals receiving 5 implants during their lifetime (538 vs. 430). Obviously, 5 implants during an animal's lifetime is more than typical. In the review by Duckett and Pratt (2014), one estrogen implant decreased marbling score by 3.75%, whereas two combination implants in an animal's lifetime decreased marbling score by 9.34% compared to non-implanted controls. Parr et al. (2011) noted no difference in marbling score when animal received either a Revalor-S implant or a Revalor-XS implant compared to non-implanted controls; however, there was a numerical shift in quality grade from USDA Premium Choice and Prime to USDA Choice for the implanted cattle compared to the non-implanted controls. Baxa et al. (2010) noted a 5% decrease in marbling score when steers were implanted with Revalor-S compared to no implant. Johnson et al. (1996) noted no difference in quality grade for cattle implanted with Revalor-S compared to non-implanted controls whether they were harvested at 40, 115, or 143 days post implanting.

As previously mentioned, growth implants improve muscle accretion and thus increase LM area and improve HCW. The use of implants typically improves HCW and LM area 5-15% compared to non-implanted controls (Johnson et al., 1996; Platter et al., 2003; Baxa et al., 2010; Parr et al., 2011; Duckett and Pratt, 2014). Interestingly, even though implants appear to reduce marbling score, data would suggest there is little to no effect of implants on 12th rib-fat thickness (Baxa et al., 2010; Parr et al., 2012). With little to no effect on 12th rib-fat thickness and the change in LM area is generally similar to the change in HCW, data would suggest there is little to no effect of implanting on USDA Yield Grade (Johnson et al., 1996; Parr et al., 2011; Duckett and Pratt, 2014).

### *Effects on Consumer Acceptability*

The increase in muscle size and decrease in amount of marbling present can have an effect on meat quality, mostly affecting meat tenderness. Platter et al. (2003) examined the effects of multiple implants over an animal's lifetime on Warner-Bratzler Shear Force (**WBSF**) and consumer sensory ratings. Average WBSF was increased for all implant protocols compared to the non-implanted control from 3.54 kg up to 4.46 kg. However, when steaks were aged 21 d, there was no difference in the number of steaks deemed tough (WBSF ≥ 4.5 kg). Consumers were able to note a difference in tenderness, in that the non-implanted cattle were found more desirable than the implanted cattle on tenderness with the same being true for juiciness and flavor. However, there were no differences noted across treatments on overall eating quality satisfaction (Platter et al., 2003). In the review from Duckett and Pratt (2014), the authors compiled data from several experiments examining the effects of implants on WBSF values and noted a wide variation in response. Scheffler et al. (2003) noted a linear increase in WBSF as number of implants administered increased. Similarly Platter et al. (2003) noted that WBSF increased until 3 implants were administered and additional implants did not further increase WBSF. There are many management factors that can play into the effects of implant on consumer acceptability: cattle type, days on feed, implant timing, implant dosage, and aging period of steaks. With proper management, decreased consumer acceptability can be mitigated. From data adopted from Smith et al. (2007), Duckett and Pratt (2014) showed that at 21 days of aging, the WBSF values were the same for animals implanted with two implants of Synovex-Plus (Zoetis, Inc. Florham Park, NJ) a very aggressive implant strategy (28 mg E and 200 mg TBA) compared to non-implanted angus steers.

### *Effects on Cost of Production*

Due to the added body weight and HCW, growth implants drastically increase returns compared to non-implanted cattle. Taking into account feed prices as well as quality grade premiums and discounts, in 1996, the benefit of administering a single estrogen implant in the feedlot was \$22.39/steer, and that added benefit has more than doubled due to the increased value of cattle to \$54.02/steer in 2013 (Duckett and Pratt, 2014). Two combination implants increased net return by \$112.53/animal in 1996, and an estimated \$218.58 in 2013. Lawrence and Ibarburu (2007) estimated that an implant administered to a suckling calf would improve cost of production by \$28.03/animal during the cow/calf phase of production; implant use during the stocker phase would improve production by \$18.19/animal and \$68.59/animal during the feedlot phase. The authors estimated the cost of removing growth implants from the entire beef industry accounting for adoption rates and found that cost would increase \$71.28/animal or increase breakeven price by 7.14% (Lawrence and Ibarburu, 2007).

## BETA-ADRENERGIC AGONISTS

### *Mode of Action*

As previously mentioned, there are currently 2 commercially available BAA on the market, ractopamine hydrochloride (Optaflexx, Elanco Animal Health) and zilpaterol hydrochloride (Zilmax, Merck Animal Health). Mersmann (1998) provided an overview of the mode of action of BAA. Beta-adrenergic agonists are catecholamines, similar to epinephrine and norepinephrine (Mersmann, 1998). As the name suggests, BAA, bind to beta-adrenergic receptors (BAR) on mammalian cells. There are 3 subtypes of BAR on mammalian cells, ($\beta_1$, $\beta_2$, and $\beta_3$), with $\beta_2$ being the most abundant (Sillence and Matthews, 1994). Zilmax has the capability of binding to both $\beta_1$, and $\beta_2$, (Baxa et al., 2010) whereas Optaflexx only binds to $\beta_1$ receptors (Moody et al., 2000; Winterholler et al., 2008). Once bound to the plasma membrane, receptors signal a response to increase myosin and actin to decrease protein degradation and increase protein synthesis (Bryant et al., 2010). Data have shown that Optaflexx works primarily by increasing protein synthesis, whereas Zilmax increases protein synthesis and slows protein degradation (Scramlin et al., 2010).

### *Effects on Animal Performance*

Similarly to implants, BAA have been shown to improve feedlot performance as well as HCW and LM area. Zilpaterol hydrochloride is approved to feed for the last 20-40 d of the feeding period at 7.5 PPM (60-90 $\text{mg}\cdot\text{animal}^{-1}\cdot\text{d}^{-1}$) with a 3 d withdrawal period (FDA, 2006). In a large study across 3 geographical locations, the use of Zilmax improved ADG and G:F by 43.5 and 46.6%, respectively, when fed for 20 d to steers, increasing total BW gain by 11.9 kg, compared to control cattle (Montgomery et al., 2009). One of the most important attributes of Zilmax is its effect on dressing percentage and HCW. In this particular study, dressing percentage was increased by 1.3 percentage units, and HCW was increased by 13 kg (Montgomery et al., 2009). Avendaño-Reyes et al. (2006) noted a 35.4% improvement in ADG and a 36.8% improvement in efficiency when Zilmax was fed for the last 33 d compared to a control, with no effect on DMI, resulting in a 19.5 kg increase in final live BW. Hot carcass weight was increased by 21.9 kg and dressing percentage was improved by 2.01 percentage units (Avendaño-Reyes et al., 2006). These results are similar to those reported by Baxa et al. (2010), where Zilmax improved ADG by 5.6% and efficiency by 6.6% for the final 91 d on feed when Zilmax was fed for the final 30 d, compared to a control, with no effect on DMI. Furthermore, HCW, was increased by 21.5 kg and dressing percentage was increased by 2.4 percentage units (Baxa et al., 2010). Holland et al. (2010) reported only a numerical increase in ADG, with a 13.3% improvement in feed efficiency for cattle fed Zilmax compared to non-fed controls, with a 0.42 kg/d reduction in DMI, and a no difference in final live BW. Hot carcass weight was increased by 11 kg, and dressing percentage was increased by 1.2% units. In a summary of 4 large pen studies using 8,647 steers, Elam et al. (2009) reported a 15.5% increase in ADG, and a

16.2% improvement in feed efficiency with no effect on DMI for d -50 to the end of the study when Zilmax was fed for 20 d compared to non-Zilmax fed controls. Final live BW was increased by 8 kg for Zilmax fed cattle compared to controls, and HCW was increased by 13.6 kg, and dressing percentage was increased by 1.36% units (Elam et al., 2009). Rathmann et al. (2012) reported a 9.5% improvement in ADG, a 0.18 kg/d reduction in DMI, and a 12.5% improvement in feed efficiency when Zilmax was fed to beef heifers for 20 d compared to controls. Final BW was increased by 4.3 kg, HCW was increased by 11.1 kg, and dressing percentage was increased by 1.52 percentage units when Zilmax was fed (Rathmann et al., 2012). Interestingly, in all of the experiments previously mentioned, the increase in HCW exceeds that of final BW when Zilmax is fed, indicating a shift of non-carcass components to the carcass towards the end of the feeding period. However, Holland et al. (2010) examined body component mass of steers and reported no difference in the weight of all non-carcass components. More research is needed to identify the location of the shifting of non-carcass components to the carcass when cattle are fed Zilmax. One could hypothesize that the difference is caused by the retention of water in the carcass, due to increased protein content.

Due to the increase in HCW compared to that of final live BW, research has been conducted to examine the effects of Zilmax on carcass gain and efficiency. This becomes particularly important when cattle are marketed on a carcass basis. Due to the fact that HCW is increased above that of live weight, it is recommended to market cattle on a carcass basis when feeding Zilmax to maximize returns. Rathmann et al. (2012) noted a 33.6% improvement in carcass ADG and a 35.9% in carcass efficiency for heifers fed Zilmax compared to non-Zilmax fed controls. Moreover, there was a 15.6% improvement when carcass ADG was expressed as a function of live ADG for cattle fed Zilmax compared to controls, further confirming that carcass gain improved above that of live weight gain (Rathmann et al., 2012). When calculated for the entire feeding period (152 d) carcass gain was improved by 10.3% and carcass efficiency by 8.7% for steers fed Zilmax the last 23 days on feed (Parr et al., 2011).

As previously noted, the beta agonist ractopamine hydrochloride (Optaflexx) binds to $\beta_1$ receptors. Optaflexx is approved to feed for the last 28-42 days at 70-400 mg·animal$^{-1}$·d$^{-1}$ with no withdrawal period (FDA, 2009). Scramlin et al. (2010) examined the effects of Optaflexx and Zilmax on feedlot performance and carcass characteristics. For the last 33 d prior to slaughter, ADG was increased by 24.2% and efficiency was increased by 22.4% for cattle fed 200 mg of ractopamine daily compared to a control not fed a beta-agonist with no effect on feed intake. However, when compared to Zilmax, cattle fed ractopamine experienced a 12.4% improvement in ADG and a 0.86 kg/d increase in feed intake, resulting in no differences in feed efficiency. In this experiment, final live BW was greatest for cattle fed ractopamine, whereas the cattle fed Zilmax had a greater final live BW than those fed no-beta agonist. However as described in the previous section, HCW was greatest for the Zilmax fed cattle, having a 7.02 kg heavier HCW than the cattle fed ractopamine. Cattle fed ractopamine had a 5.27 kg heavier HCW than the control (Scramlin et al., 2010). Similarly, dressing percentage was greatest for Zilmax fed cattle and there was no difference between the ractopamine group and the control. Avendaño-Reyes et al. (2006) showed a 31.6% improvement in ADG and a 34.1% improvement in efficiency with a 0.14 kg/d reduction in DMI for cattle fed Optaflexx at 300 mg/d for the last 33 d of the feeding period. Final BW was increased by 10.6 kg, and HCW was increased by 14 kg (Avendaño-Reyes et al., 2006). In contrast, Van Donkersgoed et al. (2011) noted no difference in ADG or feed efficiency when heifers were fed ractopamine for 29 days at 200 mg/d compared to Zilmax. Feed intake was greater for the cattle fed ractopamine compared to the heifers fed Zilmax (Van Donkersgoed et al., 2011). Hot-carcass weight and dressing percentage was increased for the heifers fed Zilmax compared to the cattle fed ractopamine. Quinn et al. (2008) noted a numerical improvement in ADG with a 9.6% improvement in feed efficiency for heifers fed Optaflexx at 200 mg/d for 28 d compared to a control. There was no difference in final live BW or HCW. Similarly, Gruber et al. (2007) noted a 15.3% improvement in ADG and a 17.2% improvement in feed efficiency with no differences in feed intake for steers fed 200 mg of ractopamine for the last

28 days on feed compared to steers fed no-beta agonist. Final live BW was increased by 7.3 kg and HCW was improved by 5.5 kg with no effect on dressing percentage when ractopamine was fed (Gruber et al., 2007). Bryant et al. (2010) examined the effects of Optaflexx dose (0, 100, or 200 mg of ractopamine) for the final 28 days on feed for feedlot steers. The feeding of 100 or 200 mg·animal$^{-1}$·d$^{-1}$ increased ADG by 0.25 kg/d compared to cattle fed 0 mg ractopamine. Furthermore, feed efficiency was increased by 3.8% during the last 28 days on feed for the cattle fed 100 or 200 mg·animal$^{-1}$·d compared to the cattle fed 0 mg/d ractopamine. There was no effect of treatment on DMI or final live BW. However, the cattle fed 200 mg ractopamine had a heavier HCW and a greater dressing percentage. Additionally, in another experiment, the feeding of 250 mg/d ractopamine to heifers for the last 28 days on feed resulted in a 60.6% improvement in ADG and a 60.3% improvement in feed efficiency compared to control heifers, resulting in a 10 kg increase in final live BW and a 6.5 kg increase in HCW by feeding ractopamine (Bryant et al., 2010).

### *Effects on Carcass Characteristics*

The data referenced above indicate an increase in protein accretion in animals fed Zilmax due to an increase in HCW. However, with an increase in HCW some tradeoffs occur concerning other carcass parameters. Generally, cattle fed Zilmax have an increased LM area, results are variable concerning 12th-rib fat thickness, and marbling score is generally decreased. Montgomery et al. (2009) noted a 4.2 cm$^2$ increase in LM area, no effect on 12th rib-fat thickness, and a numerical decrease in marbling score for cattle fed Zilmax for the last 20 d compared to controls. The slight decrease in marbling score did not affect USDA Quality Grade distribution, however, USDA Yield Grade was shifted to a more desirable yield grade when Zilmax was fed. Rathmann et al. (2012) noted similar results with a 5.6 cm$^2$ increase in LM area for heifers fed Zilmax compared to controls; however, there was a 0.08 cm reduction in 12th rib-fat thickness, resulting in a lower calculated Yield Grade, as well as a lower marbling score (Rathmann et al., 2012). The decrease in marbling score resulted in a 6% decrease in carcasses grading USDA Choice and an increase in carcasses grading USDA Select. Baxa et al. (2010) reported similar results in which LM area was increased and fat thickness and marbling score were reduced when cattle were fed Zilmax for the last 30 days on feed. Parr et al. (2011) noted no differences in 12th-rib fat thickness or marbling score, resulting in no differences in USDA Quality Grade or Yield Grade distributions for steers fed Zilmax compared to controls. Garmyn et al. (2011) selected carcasses from Parr et al. (2011) for equal HCW and noted an increase in LM area with no effect on fat thickness, marbling score, USDA Yield Grade or percentage of carcasses grading USDA Choice when Zilmax was fed.

Data suggest that feeding Optaflexx for the last 28-42 d of the feeding period does not drastically affect carcass characteristics. Scramlin et al. (2010) noted no difference in LM area, 12th rib-fat thickness, USDA Yield Grade or marbling score for cattle fed Optaflexx for the last 33 d compared to controls. Similarly, Bryant et al. (2010) noted no difference in LM area, adjusted 12th rib-fat thickness USDA YG or marbling score for steers fed 100 mg of ractopamine. At 200 mg of ractopamine, the same was true, except LM area was increased by 2.3 $cm^2$ (Bryant et al., 2010). Additionally, there was no effect of ractopamine on USDA Quality Grade or Yield Grade distribution. Bryant et al. (2010) reported the same results for heifers fed 250 mg/d ractopamine compared to controls. Again, similar results were shown by Gruber et al. (2007) where a 2.3 $cm^2$ increase in LM area was noted, with no effect on fat thickness or USDA Yield Grade; there was a trend for a 10 unit decrease in marbling score for cattle fed 200 mg/d Optaflexx compared to controls. The slight increase in LM area shifted USDA YG resulting in a greater percentage of USDA YG 2 (Gruber et al., 2007). There was no effect on USDA Quality Grade distributions (Gruber et al., 2007). When Optaflexx was fed at 300 mg/d, Avendaño-Reyes et al. (2006) reported a numerical increase in LM area and no effect on 12th rib-fat thickness compared to a control.

### *Effects on Consumer Acceptability*

Similar to implants, due to the increase in muscle, data indicate a slight decrease in tenderness when Zilmax is fed. Leheska et al. (2009) noted a 0.72 kg increase in WBSF for steers fed Zilmax for 20 d compared to controls. Sensory evaluation by a trained panel determined a decrease in overall tenderness and an increase in flavor intensity for the steers fed Zilmax. Also, a numerical reduction in overall juiciness was noted, however there was no effect of Zilmax on beef flavor (Leheska et al., 2009). When fed to heifers, the results on shear and sensory attributes were similar (Leheska et al., 2009). A 0.84 kg increase in WBSF was noted with a reduction in juiciness, tenderness, flavor intensity and beef flavor for heifers fed Zilmax for 20 d compared to heifers fed no beta-agonist (Leheska et al., 2009). When selected for equal HCW across treatments, Garmyn et al. (2011) noted an increase in WBSF for steaks from cattle fed Zilmax with 7, 14, 21, 28, or 35 days aging. However, there was no effect of Zilmax on the percentage of steaks being considered tender (WBSF < 4.6 kg; Garmyn et al., 2011). Similarly Rathmann et al. (2012) noted an increase in WBSF and slice shear force (SSF) for steaks from heifers fed Zilpaterol compared to controls for up to 21 days of aging. Moreover, Hilton et al. (2009) noted an increase in WBSF for steaks from animals fed Zilmax compared to controls over 7, 14, and 21 d aging period. During a trained sensory panel, steaks from animals fed Zilmax were noted has having lower sustained juiciness, lower sustained tenderness, and lower overall mouth feel than control steaks, indicating a lower eating quality. However, during a consumer panel, there was no difference between treatments on overall acceptability or tenderness acceptability. The consumers did determine that the steaks from the cattle fed Zilpaterol were less tender, however, these steaks were still deemed as acceptable (Hilton et al., 2009).

Scramlin et al. (2010) noted an increase in WBSF values for steaks from cattle fed Optaflexx for the last 33 d compared to controls at 3 and 7 d of aging. However, when the steaks were aged for 14 or 21 d, there was no difference in WBSF. In contrast, Quinn et al. (2008) noted no effect of Optaflexx on WBSF of heifers fed 200 mg/d for the last 28 days on feed compared to a control. Arp et al. (2013) examined the effects of 200, 300, or 400 mg/d Optaflexx, compared to a negative control and Zilmax on WBSF and slice shear of steaks. The cattle fed 400 mg/d Optaflexx had a greater WBSF value compared to the control steaks as well as those from cattle fed 200 or 300 mg/d Optaflexx, but less than steaks from cattle fed Zilmax. In a trained sensory panel, cattle fed 300 or 400 mg/d Optaflexx had a lower overall tenderness score, indicating less tender than the control cattle. There was no effect of treatment on juiciness or beef flavor (Arp et al., 2013). Similarly, Howard et al. (2014) showed that calf-fed Holsteins fed 300 or 400 mg/d ractopamine had 2.3 kg greater slice shear force values than control cattle, but 1.9 kg lower slice shear values than cattle fed Zilmax at 14 d aging. When steaks were aged 21 d the cattle fed 300 and 400 mg/d Optaflexx had an increased slice shear value by 1.7 kg and were 0.5 kg lower than the cattle fed Zilmax (Howard et al., 2014). Interestingly, if the carcass graded Low Choice, the probability that the steaks would be certified as tender (Slice Shear < 20 kg) was not different, regardless of length of age (Howard et al., 2014). However, if the steaks were aged 21 d and graded USDA Select, the cattle fed Zilmax had a higher probability of being classified 'not-tender' than the cattle fed Optaflexx or the controls (Howard et al., 2014). In a trained sensory panel of the Low-Choice carcasses aged 21 d, the cattle fed 300 mg/d Optaflexx had similar overall tenderness and juiciness values as compared to the control cattle (Howard et al., 2014).

### ***Effects on Cost of Production***

In 2007, Lawrence and Ibarburu, estimated the effects of the removal of BAA from feedlot production. Due to the timing of this article and the approval of Zilmax in 2006, it is likely that the data reflected in this analysis are for Optaflexx only, however, the authors did not clarify. However, it was estimated that the removal of BAA would increase breakeven price by 1.24% and increase cost of production by $13.02/animal (Lawrence and Ibarburu, 2007). Schroeder and Tonsor (2011) estimated that Zilmax increased net returns by $21/animal to cattle feeders and $31/animal to beef packers due to increased red-meat yield. When accounting for weighted averages of effects of Optaflexx and Zilmax, Johnson et al. (2014) estimated an increase in profitability of $42.47/animal with the use of beta agonists to the feedlot industry.

## IONOPHORES AND ANTIBIOTICS

### *Mode of Action*

The other 2 technologies widely used in beef production are feed-grade ionophores and antibiotics, mostly monensin (Rumensin, Elanco Animal Health) and tylosin (Tylan, Elanco Animal Health). As described by Duffield et al. (2012), monensin is an ionophore fed orally to cattle that inhibits Gram-positive bacteria, increases metabolic efficiency, improves protein metabolism and helps reduce digestive disorders. The main mechanism by which monensin increases efficiency is by selecting for bacteria that improves propionate production and reduces butyrate and acetate (Duffield et al., 2012). Since propionate is the main source of glucose in ruminants and used as a gluconeogenic substrate, energy efficiency can be improved if the proportion of propionate can be increased (Ellis et al., 2012). Furthermore, if propionate is increased in relation to butyrate and acetate, hydrogen will be reduced thus improving methane emissions (Ellis et al., 2012). Another benefit of monensin is its inhibitory effects of lactic acid producing bacteria such as *S. bovis* and *Lactobacillus* (Cheng et al., 1998), the main drivers of feedlot bloat and lactic acidosis.

Tylosin, the main feed grade antibiotic fed to feedlot cattle, is used to prevent *Fusobacterium necrophorum* and *Actinomyces pyogenes*, the main bacteria blamed for the cause of liver abscesses in cattle (Nagaraja and Chengappa, 1998). Tylosin is a macrolide antibiotic that works to mainly inhibit Gram-positive bacteria, however, *F. necrophorum*, a Gram-negative bacteria, is also susceptible to tylosin. Nagaraja and Chengappa (1998) discussed that tylosin works to primarily reduce the growth of these bacteria in the rumen, but it can be effective in the liver as well.

### ***Effects on Feedlot Performance and Carcass Characteristics***

In a meta-analysis of 169 trials, the effects of monensin on feedlot performance were analyzed (Duffield et al., 2012). The mean dose in this summary was 28.1 mg/kg feed. The results indicated that the inclusion of monensin in feedlot diets reduced DMI by 0.268 kg or 3.1%, ADG was increased 0.0291 kg/d or 2.5%, resulting in a 6.4% reduction in kg feed/kg BW gain (Duffield et al., 2012). Interestingly, there has been a linear decrease in the effectiveness of monensin from the 1970s to the 2000s from 8.1 to 3.5% improvement in feed efficiency, probably due to increased management as well as implementation of other technologies (Duffield et al., 2012). Stock et al. (1995) noted a 1.4% reduction in DMI, an increase in ADG, and a 4% improvement in feed efficiency when feeding monensin at 33 mg/kg compared to 0 mg/kg. Moreover, day to day variation in feed intake was reduced when 27 mg/kg monensin was fed compared to 0 mg/kg (Stock et al., 1995). Depenbusch et al. (2008) examined the effects of monensin and tylosin in steam-flaked corn finishing diets containing wet distiller's grains with solubles (**WDGS**). Results from this study showed no difference in feedlot performance compared to a control, with or without WDGS. Moreover, there was no effects on carcass characteristics (Depenbusch et al., 2008). Although not statistically significant, there was a numerical decrease in the number of animals exhibiting liver abscesses at slaughter in the diet containing steam-flaked corn, however, this was not noted in the diets containing WDGS (Depenbusch et al., 2008). Meyer et al. (2013) conducted a similar experiment and reported a reduction in DMI when monensin was fed in combination with tylosin at either 31.7 mg/kg or 42.3 mg/kg compared to 0 mg/kg when WDGS was included in the diet, with an equal combination of dry-rolled corn and high-moisture corn. There was no effect of treatment on ADG, however, monensin inclusion in the diet at 31.7 mg/kg in combination with tylosin improved feed efficiency by 4.9% and when in the diet at 42.3 mg/kg, feed efficiency was improved by 3.7% (Meyer et al., 2013). There was no effect of monensin and tylosin inclusion on carcass characteristics. There was a 34.1 percentage unit decrease in abscessed livers when monensin and tylosin were fed compared to a negative control (Meyer et al., 2013). When steam-flaked corn was the basal grain in the diet with WDGS, DMI was not affected by monensin and tylosin inclusion, however, ADG and efficiency was improved resulting in a 5 kg improvement in HCW (Meyer et al., 2013). Additionally, liver abscesses were reduced by 28 percentage units with monensin and tylosin compared to a negative control (Meyer et al., 2013). Tylosin has been shown to effectively reduce liver abscesses. Vogel and Laudert (1994) reported a 2.3% improvement in ADG, a 2.6% improvement in feed efficiency and a 73% reduction in liver abscess occurrence with the feeding of tylosin.

### *Effects on Cost of Production*

As discussed above, monensin increase productivity in feedlot cattle mostly by improving feed efficiency, and tylosin reduces liver abscesses. Brown and Lawrence (2010) reported that an animal with a 'A-' or 'A' liver score would have approximately a $5.00/animal lower net return than an animal without a liver abscess. However if the liver abscess became severe, net returns are reduced by as much as $38.26/animal (Brown and Lawrence, 2010). Lawrence and Ibarburu (2007) determined that removal of ionophores from the feedlot segment would increase breakeven price by 1.18% and increase cost of production by $12.43/animal. If antibiotics were removed, breakeven price would increase by 0.56% and cost of production would increase by $5.86/animal (Lawrence and Ibarburu, 2007).

## ENVIRONMENTAL IMPACTS OF TECHNOLOGIES

As discussed in the introduction, one of the major factors in sustainability is environmental impact. Stackhouse-Lawson et al. (2013) examined the effects of growth promoting technologies on greenhouse gas emissions as well as other environmental factors in a feedlot situation. Angus steers were used to test the effects of a control diet containing no technologies to a monensin and tylosin treatment, monensin, tylosin, and growth implants, and finally all technologies combined with the feeding of Zilmax. Average daily gain was increased and efficiency was improved with the use of all technologies compared to the control. The use of all technologies resulted in 39 kg increase in HCW compared to the control. Interestingly marbling score was not affected by the treatments (Stackhouse-Lawson et al., 2013). Methane emissions were reduced by 16.4% for the cattle given all technologies compared to the control, and ammonia emissions were reduced by 29.6%. Cooprider et al. (2011) estimated a 31% reduction in emissions per animal for animals produced with conventional technologies including a BAA compared to animals produced without the use of technologies. Conventional production reduced carbon dioxide equivalent production by 1.10 kg per kg BW gain compared to animals produced without the use of technologies (Cooprider et al., 2011). Moreover, (Stackhouse, 2012) showed a 4% and 9% reduction in carbon footprint for the use of implants and implants combined with BAA compared to no technology use, respectively in a simulated model. Capper (2012) estimated the effects of conventional, natural and grass-fed production systems on resource use to produce 1.0 x $10^9$ kg of beef. Conventional production including the use of all available technologies, reduced the amount of land needed by 1221 x $10^3$ ha, and the amount of water required by 86779 x $10^6$ liters compared to natural production. The amount of manure was reduced by 8455 x $10^3$ t and total carbon footprint was reduced by 2783 carbon equivalents (Capper, 2012) for conventional beef production compared to natural production.

## CONCLUSIONS FROM LITERATURE

Literature regarding the use of technologies in beef production suggests that they are quite effective in increasing performance and saleable product all while improving cost of production and decreasing environmental impact. The overall theme of the literature suggests that some decreases in tenderness occur, but the differences are not substantial enough to warrant concern from the consumers. Data are lacking where technology use is examined in a systems fashion. Most of the conclusions about the interactions and effects of multiple technologies have to be calculated across studies. Most especially the economic impact of technologies has had to be modeled or calculated using study averages across various studies. As increased societal concerns continue to escalate due to technology use, more scientific data relating to the system effects of technology use compared to all-natural or organic systems is necessary. The experiments presented within this dissertation were designed to address multiple questions regarding the use of technologies in beef production and further add to the knowledge needed to continue to increase beef production and beef production sustainability.

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# CHAPTER III

## EFFECTS OF BEEF PRODUCTION SYSTEMS ON ANIMAL PERFORMANCE AND CARCASS CHARACTERISTICS – YEAR I

**ABSTRACT**: The objective of this study was to evaluate conventional and natural beef production systems through grazing annual pasture and finishing. Beef steers (n = 180; initial BW = 250 ± 19 kg) were randomized to one of two treatments in the pasture phase. Steers were implanted with 40 mg of TBA, 8 mg estradiol, and 29 mg tylosin tartrate (Conventional; CONV) or received no implant (Natural; NAT). Steers on the 2 treatments were comingled and grazed wheat or 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/trt) 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% 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 daily 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 steers compared to 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 (3.09 vs. 3.54; $P < 0.01$) for CONV steers compared with NAT steers. Natural steers had a higher percentage of carcasses in the upper 2/3 of USDA Choice grade (48.7 vs. 18.7%; $P < 0.01$), a higher percentage of USDA Yield Grade 4 and 5 carcasses (25.4 vs. 9.3%; $P < 0.01$), and a higher percentage of abscessed livers (39.6 vs. 10.5%; $P < 0.01$) compared with CONV steers. The results show that CONV production results in significant improvement in annual pasture and feedlot, resulting in heavier carcasses with superior yield grades and acceptable quality grades regardless of roughage level.

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

## 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 conventional beef production have increased in market share, and many consumers perceive benefits of consuming beef products from cattle produced in organic, grass-finished conditions or without using antibiotics or growth promoting technologies in livestock. Some producers have modified their production practices to target these markets because they believe these products are superior or because they have observed price premiums. 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 conventional, natural, 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 the advantages producers can gain by using modern technologies. In the twoseries papers by Fernandez and Woodward (1999), they examined the effects of conventional 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 (Wileman et al., 2009).  Recently, Cooprider et al. (2011) completed a study examining the effects of conventional vs. natural feedlot practices.  Therefore, the study outlined below was designed to fully evaluate the effects of natural and conventional beef production systems with differing roughage levels on animal performance and carcass characteristics during an annual pasture phase and feedlot finishing phase with genetically similar animals.

## 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.  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-Natural program.  The steers had received no-implants or antibiotics prior to 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 which of the 4 locations the calves originated from. After obtaining the initial BW, steers were randomly allocated to one of 2 treatments for the annual pasture phase of the experiment. Cattle received either an implant containing 40 mg/steer trenbolone acetate, 8 mg estradiol and 29 mg tylosin tartrate (**CONV**; Component TE-G; Elanco Animal Health, Greenfield, IN) or no-implant (**NAT**). Cattle were stratified across treatment by ranch location of origin. The animals were allowed to graze for 109 d on 2 locations with each treatment equally represented within location. Location 1 was a 121 ha pasture planted to hard red winter wheat (*Triticum aestivum*; variety = Duster) containing 112 steers and location 2 was a 93 ha pasture planted with cereal rye (*Secale cereal*; variety = Elbon) containing 68 steers. Forage mass samples were obtained on December 01, 2011 and March 01, 2012 to determine forage mass available for grazing (Table 3.1). 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 kg of DM/hectare. On February 28, 2012 and March 5, 2012, cattle from location 1 and 2, respectively, were gathered and immediately loaded and hauled (~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 body weight obtained upon arrival was utilized as the final BW of the annual pasture phase. Steers were held in respective groups and fed approximately 2% BW (DM Basis) of RAMP without monensin (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 % intramuscular fat (**IMF**) of each animal were obtained by ultrasound. On March 12, 2012 all calves were weighed prior to AM feeding to determine finishing phase allocation weight. Steers were 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 roughage level (7% diet DM [**LOW**] or 12% diet DM [**HIGH**]). The CONV steers were the animals that received a growth implant during the pasture phase, and the NAT steers consisted of the animals that did not receive a growth implant during the pasture phase. From the original 180 steers, 160 steers were chosen for the finishing phase. The steers were culled based upon BW or other issues noted (lameness, poor performance, etc.) Within production system, steers were blocked by BW (2 weight blocks) and carcass ultrasound data was utilized to stratify the animals within production system across roughage level to ensure equal body composition at initiation of experiment. Steers were sorted into study pens (2 blocks; 4 replications/block; 8 pens/treatment; 5 steers/pen; 40 steers/treatment). Steers receiving NAT/LOW were tagged with an orange treatment tag, NAT/HIGH a blue tag, CONV/LOW a purple tag and CONV/HIGH a green tag. On d 0, randomization to treatments, all steers were vaccinated against clostridial toxins (Caliber 7; Boehringer Ingelheim, St. Joseph, MO), IBR, PI3, BRSV, and BVD type 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 × 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 prior to AM feeding. Carcass ultrasound was also performed at d 70 to predict body composition so that cattle could be marketed at an equal body composition. A 4 % shrink was applied to all BW for calculation of performance. On d 135, all cattle were weighed at 0000 h. This BW was used as final live BW. 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, CONV cattle were slaughtered on Thursday of each week and graded on the following Tuesday (120 h), whereas the NAT cattle were slaughtered on Friday of each week 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 scores were obtained 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 is show in Tables 3.2 and 3.3, respectively. All diets were formulated to meet or exceed NRC (2000) requirements. All CONV diets contained 33 mg/kg monensin and 9 mg/kg tylosin, with NAT containing no monensin or tylosin. For all diets, minerals, vitamins and feed additives were contained in a ground corn and wheat middling based pelleted supplemented mixed at the Oklahoma State University Feed Mill. Cattle were adapted to assigned finishing diets during a 22 d adaption period. During this phase, CONV steers were fed a portion of RAMP with monensin and their treatment diet, and the NAT calves 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 calves were adapted to the finishing diet. Following adaption, calves 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. Feed bunks were managed to contain trace amounts of feed, and bunks were cleaned prior to each feeding to remove manure, hair, etc. A 76 L concrete water tank (Model J 360-F, Johnson Concrete, Hastings, NE) was shared between two adjacent pens and was cleaned three times weekly throughout the 135-d experiment.

All steers were fed a direct-fed microbial (Bovamine, Nutrition Physiology Company, Guymon, OK) at 1 $g \cdot steer^{-1} \cdot d^{-1}$. 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 AM and PM feeding. Beginning on d 112, CONV steers were fed zilpaterol hydrochloride (Zilmax; Merck Animal Health, DeSoto, KS) at 90 $mg \cdot steer^{-1} \cdot d^{-1}$ for 20 d followed by a 3 d zilpaterol withdrawal period. Conventional rations were sampled (n = 10) and sent to Merck Animal Health Laboratory (Lawrence, KS) for zilpaterol hydrochloride assay. 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.

Ration samples were collected once/wk, dried in a forced air oven for 48 h at 60°C to determine DM. An average DM was calculated for the feeding period and actual DMI consumption was calculated at the end of the study by dividing total pounds 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 zilpaterol hydrochloride (Merck Pharmaceutical Laboratory; Lawrence, KS). Orts were obtained on each weigh-day and during inclement weather events. A DM was obtained and feed was removed from total feed delivered for accurate DMI calculation.

### ***Performance Calculations***

Diet DM formulation was calculated by adjusting the as-fed formulation by the average weekly ingredient DM determined (Table 3.2). Overall feedlot performance was calculated including all dead cattle 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; Pred. dress = [0.03 x 4% shrunk BW, kg] + 46.742) to calculate HCW (Table 3.6). Carcass adjusted feedlot performance was calculated using the average dressing percentage of all cattle of 63.90% (Table 3.7). Calculated carcass gain and efficiency was calculated for both the entire feeding period as well as when Zilmax was fed. Carcass performance for the entire feeding period was calculated using the equation from Parr et al. (2011) to predicted initial dressing percentage and HCW. For carcass performance during the Zilmax period, a dressing percentage of 63% was assumed for all cattle to estimated initial carcass weight (Table 3.7). Dietary $NE_m$ and $NE_g$ calculations were performed by using the Standard Reference Weight of 478 kg for animals finishing with small marbling (Table 3.9; NRC, 2000). Energy expended for maintenance and retained energy were calculated based upon actual performance and DMI using Eq. 3-1 (NRC, 2000). The $NE_m$ and $NE_g$ values were then solved using the equation described by Zinn et al. (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 experimental unit, and weight block was included as a random effect. The USDA Quality grade, Yield Grade and liver scores were analyzed using PROC GLIMMIX (SAS 9.3; SAS Inst. Cary, NC). All production system × roughage level interactions were considered different and means were separated using Tukey adjustment method when overall ANOVA was significant ($P < 0.05$).

# RESULTS

## *Forage Availability*

Forage mass availability and stocking rates during the pasture phase are shown in Table 3.1. Forage allowance was greater in location 2 than location 1 throughout the grazing phase. This was mostly due to the lower stocking rate for location 2 compared to location 1, and more forage DM/ha in location 2. Fieser et al. (2006) 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 similar (1.12 vs. 1.14 kg/d; $P = 0.52$) suggesting adequate forage was available at each location. All treatments were equally represented within each location and location was used as a random effect in the model for the feedlot performance data; therefore, the difference in forage allowance between locations did not appear to affect treatment response.

## *Feedlot Diet Analyses*

Diet DM formulations fed throughout the study (Table 3.2) are similar to finishing diets fed throughout the industry. These diets were formulated to meet or exceed NRC requirements (NRC, 2000). Formulations were targeted to be similar between CONV and NAT within each roughage level. Diets were formulated to contain adequate NPN to meet DIP requirements. The vitamin and mineral supplements were the same for each diet, 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. All other vitamins and minerals were formulated to meet NRC requirements. Analyzed nutrient composition of the diets fed (Table 3.3) would indicate that the goals of the formulation were met. Crude protein was in excess for both diets, due to the high inclusion of corn byproducts fed. It is notable that the analyzed fat values were slightly higher in the CONV diets than in the NAT diets; however, the difference is most likely due to sampling error.

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

Zilpaterol hydrochloride was assayed from the composited weekly samples during the period in which zilpaterol 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 (PAV). The difference between the two assayed values is 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 upon actual DMI during the zilpaterol hydrochloride period, zilpaterol hydrochloride intake was 92.9 and 84.63 mg$\cdot$steer$^{-1}\cdot$d$^{-1}$ for CONV-LOW and CONV-HIGH, respectively, similar to the labeled dose of 70 to 90 mg$\cdot$steer$^{-1}\cdot$d$^{-1}$.

### *Cattle Performance on Pasture*

Cattle performance during the pasture phase is shown in Table 3.4. 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 less ($P < 0.01$) FT and contained less ($P < 0.01$) IMF (Table 3.5). Conventional steers tended ($P = 0.09$) to have a larger LM; however, CONV had a lower ($P = 0.04$) LMA/BW ratio compared with NAT.

### ***Production Program x Roughage Level Interactions***

One of the objectives of this experiment was to determine the appropriate roughage level for NAT cattle fed no ionophore. 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.

### ***Feedlot Performance – Live Basis***

Interim and overall feedlot performance is shown in Table 3.6. As mentioned previously, BW was greater (21 kg; $P < 0.01$) for CONV steers compared with NAT steers; however, 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 (Table 3.5). Therefore, LMA and IMF were similar ($P \geq 0.63$) for LOW and HIGH steers. Fat thickness was different ($P < 0.01$) between LOW and HIGH steers. However, the biological and economical relevance is in question due to the small difference (0.45 vs. 0.43 cm for LOW and HIGH, respectively).

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 (Table 3.6). During d 0 to 69, there was a tendency ($P = 0.06$) for CONV calves to consume more feed than NAT calves. There was no difference ($P = 0.86$) in DMI from d 70 to 111. However, CONV calves consumed 7.8% more feed from d 112 to 135 ($P < 0.01$) feed than NAT calves, resulting in an increase (6.9%; $P = 0.01$) in DMI for the 135 d feeding period. Conventional calves 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% improvement ($P < 0.01$) in calculated dietary $NE_m$ and a 14.9% improvement ($P < 0.01$) in dietary $NE_g$ for CONV steers compared to NAT steers (Table 3.9).

There were no differences ($P \geq 0.52$) in feedlot performance from d 0 to 69 due to roughage level (Table 3.6). 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 maintenance energy and a 5.9% improvement in calculated energy for gain for LOW steers compared with HIGH steers ($P < 0.01$; Table 3.9).

### *Feedlot Performance – Carcass Basis*

Feedlot performance calculated on a carcass basis is presented in Table 3.7. 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 percentage 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 zilpaterol hydrochloride was fed resulted in 0.76 kg/d greater ($P < 0.01$) carcass gain and a 64.0% improvement in carcass efficiency ($P < 0.01$).

On a carcass adjusted basis, LOW steers had greater ($P \leq 0.03$) ADG and G:F compared with HIGH steers. Calculated overall carcass efficiency was increased ($P = 0.02$) by 6.8% for LOW steers compared with HIGH steers regardless of production program.

### *Carcass Characteristics*

Based on the d 70 carcass ultrasound measurements (Table 3.5) there were no differences in 12th rib-fat thickness between CONV and NAT steers; therefore, it was determined that all cattle should be slaughtered at the same DOF. Dressing percentage was increased ($P < 0.01$) by 1.58 percentage units resulting in a 62 kg heavier ($P < 0.01$) HCW for CONV steers compared with NAT steers. Twelfth rib-fat thickness was similar ($P = 0.53$) for CONV steers and NAT steers. *Longissimus dorsi* 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, USDA Yield Grade was lower ($P < 0.01$) for CONV steers compared with NAT steers. There was a 19.9 percentage unit increase in USDA Yield Grade 2, and a 16.04 percentage unit decrease in USDA Yield Grade 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; however, this decrease in marbling score only resulted in a shift of carcasses grading USDA Premium Choice to Low Choice ($P \leq 0.05$). There was a tendency ($P = 0.06$) for a 12.9 percentage unit decrease in USDA Choice or greater to USDA Select. Cattle fed conventionally had a 29.1 percentage unit decrease ($P = 0.02$) in abscessed livers, with a 15.3 percentage unit decrease in livers scored A+, and a trend ($P = 0.06$) for a 10.7 percentage unit decrease in livers scored A, compared with NAT steers.

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 severity for LOW steers compared to HIGH steers for those livers that contained abscesses.

## DISCUSSION

The objectives of this study were to examine the differences in pasture and feedlot performance and carcass characteristics between CONV and NAT cattle fed differing roughage levels. Previously, live animal experiments have been completed examining the differences between CONV, NAT and organic production (Fernandez and Woodward, 1999; Woodward and Fernandez, 1999; Cooprider et al., 2011), and one meta-analysis 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 the main driver of endpoint, a common predictor of physiological endpoint.

The results of the grazing phase are similar to others reported in the literature. The 0.19 kg/d advantage for CONV during the pasture phase is similar to results reported by McMurphy et al. (2013) and Sharman et al. (2012) for implanted steers grazing similar pastures. These authors reported a 0.10 and 0.13 kg/d advantage, respectively, when administering Component TE-G both resulting in a 25 kg heavier BW at the end of grazing compared to no implant. 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 summer warm-season grazing period when cattle were implanted with

Component TE-G compared to no implant.  The increase in ADG is greater in the present study compared to the published studies, potentially due to the amount of available forage and lower stocking rates in the present experiment.

There were clear improvements in feedlot performance when cattle were fed CONV compared to NAT in the present experiment.  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 to cattle that had never received any of the technologies.  Their results were similar to the 0.42 kg/d increase in ADG for CONV compared to NAT in the present experiment.  Capper (2012) predicted gains almost identical to those calculated in the present experiment for CONV and NAT fed cattle.  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 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 et al. (1994) showed a 0.81 kg/d increase in DMI for steers implanted during the growing period and during the finishing period compared to cattle never implanted, similar to the 0.76 kg/d increase experienced in the present study.  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) may be masked due to the implant during the stocker phase.  Cooprider et al. (2011) observed a 33.3% improvement in feed efficiency when feeding cattle conventionally compared to naturally.  This is greater than the 24.2% improvement in the present study; however, this is potentially due to the additional 42 days the natural 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 at the end of the study, especially on a carcass basis, and thus feeding natural cattle past their optimum compositional endpoint could decrease gain efficiency.

Zilpaterol hydrochloride was fed to the CONV cattle in this study due to its advantageous effects on carcass weight and value when marketing cattle in the beef or on a grid basis. Parr et al. (2011) examined the effects of anabolic implant in combination with zilpaterol hydrochloride on carcass gain and efficiency at the end of the feeding period. The authors noted no implant by zilpaterol interaction, indicating that these two technologies are additive. Over a 152 d feeding period, 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 to no implant, and a 0.12 kg/d increase in carcass ADG and a 8.7% improvement in efficiency when feeding zilpaterol hydrochloride 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 to NAT over the entire feeding period. Rathmann et al. (2012) examined the effects of zilpaterol hydrochloride 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 zilpaterol. In the present experiment there was a 0.76 kg/d increase in carcass ADG, and a 64% increase in carcass efficiency over the last 23 days of the feeding period for CONV compared to NAT. Most likely, the large disparity in this 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 percentage units when cattle are fed zilpaterol (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 percentage unit increase in dressing percentage for CONV vs. NAT. Parr et al. (2012) 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 to non-implanted cattle. Cooprider et al. (2011) showed no difference in dressing percentage for conventional vs. natural cattle when ractopamine hydrochloride was fed.

The reported increase in dressing percentage due to the feeding of zilpaterol hydrochloride typically results in 13 to 15 kg additional HCW when cattle are fed zilpaterol. In the present experiment, with 2 implants and the feeding of zilpaterol hydrochloride, HCW was increased 62 kg compared to NAT. Cooprider et al. (2011) only reported a 6 kg increase in HCW between natural and conventional cattle fed ractopamine hydrochloride; however, natural cattle in that study were fed longer in order to target a similar final BW. Sawyer et al. (2003) reported a 35 kg increase in HCW for cattle implanted twice during the finishing period, compared to no implants, and no difference in HCW for steers being fed monensin and tylosin, compared to those not being fed the two additives. Again, assuming that implants and zilpaterol hydrochloride are additive, Parr et al. (2011) reported a 47 kg increase in HCW with the use of both technologies compared to 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 conventionally compared to a natural 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) saw an increase in LM area for steers receiving Revalor-S and fed zilpaterol hydrochloride compared to non-implanted steers not fed zilpaterol. Similarly, Cooprider et al. (2011) reported a large increase in LM area for conventional cattle compared to natural cattle. As per the current study design, there were no effects of treatment on 12th rib-fat thickness. This was done to insure commercial applicability of the results of this experiment. Surprisingly, the cattle in this experiment on both treatments had the same amount of FT from d 0 (ultrasound) through harvest. Cooprider et al. (2011) noted an increase in FT for natural cattle compared to conventional cattle when fed to the same weight. Due to the increase in HCW and LMA for CONV steers, there was a significant impact in shift in USDA Yield Grades from YG 3 to YG 2 compared to 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 yield grade or shift in USDA Yield Grade distribution for cattle implanted or fed beta 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 yield grade. In addition, even though both groups of cattle carried the same amount of FT, the LM area were much smaller in the natural cattle, resulting in higher yield grades. Perhaps natural cattle should be marketed with less FT than conventional cattle, offsetting smaller LM area and maintaining desirable USDA Yield Grades.

Our data are similar to other published data suggesting a reduction in marbling score and shift in USDA Quality Grades for cattle receiving technologies compared to 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 zilpaterol on marbling scores. It is interesting to note that high quality of the cattle used in the experiment, with more than 70% grading USDA Choice or better. The shift in USDA Quality Grades for cattle fed with technology was not from Choice to Select. Instead, the shift occurred within the Choice grade with fewer CONV carcasses in the upper 2/3 of Choice compared to NAT. This is in contrast to Rathmann et al. (2012) and Montgomery et al. (2009) reported a 6 percentage unit increase in the number of cattle grading USDA Select when zilpaterol was fed and Bryant et al. (2010) reported a 12 percentage 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 conventional and natural cattle. 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 natural programs. There is a marked decrease in dressing percentage, HCW, FT, and LMA for cattle exhibiting abnormal livers compared to 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 mortalities animals: 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 dead animals, 4 were diagnosed as digestive deads and 1 CONV/HIGH was euthanized due to being lame. Due to the low numbers in this experiment, the mortality 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 cattle due to digestive disorders in CONV (3 vs. 1) compared to NAT. Furthermore, these data suggest that feeding NAT cattle similar amounts of roughage as CONV did not increase digestive disorders of NAT cattle in this study. 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 very low quality and could be a contributing factor as to why the NAT cattle performed better with a lower roughage inclusion level. 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 is no published data pertaining to roughage requirements for NAT cattle. The slight increase in DMI for HIGH compared to LOW is supported by Galyean and Defoor (2002). As NDF in the diet increases, 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 function even in the NAT cattle not fed monensin. It has been well established throughout the literature that 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, 2002). However, one must remain cognizant about providing enough dietary roughage to minimize the amount of digestive disorders.

## 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 feedlot cattle. Based upon 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 to NAT steer is enough to feed 1.66 more US Citizens per year per animal (USDA ERS, 2013). As society has increasing concern over technologies used in animal production, it will be imperative to continue to communicate 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: economically advantageous, environmentally friendly and socially acceptable (Cooprider et al., 2011).

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**Table 3.1.** Forage mass availability and stocking rates during pasture phase

| | Initial Samples | | Final Samples | |
|---|---|---|---|---|
| Item | Location 1 | Location 2 | Location 1 | Location 2 |
| Steers/ha | 0.93 | 0.73 | 0.93 | 0.73 |
| Forage DM/ha, kg | 1,040.5 | 1,259.85 | 1,020.77 | 1,591.51 |
| Forage DM/steer, kg | 1,127.37 | 1,725.40 | 1,106.55 | 2,178.35 |
| Forage DM/100 kg BW, kg | 419.10 | 745.80 | 286.7 | 597.30 |

**Table 3.2.** Ingredient composition (% DM basis) of diets fed

| | Experimental diet | | | |
|---|---|---|---|---|
| | NAT | | CONV | |
| Ingredient | LOW | HIGH | LOW | HIGH |
| Dry-rolled corn | 47.91 | 42.90 | 47.90 | 42.89 |
| Switchgrass hay | 7.04 | 12.06 | 7.04 | 12.06 |
| Dried distillers grains | 14.75 | 14.75 | 14.75 | 14.75 |
| Sweet Bran® | 14.76 | 14.76 | 14.76 | 14.76 |
| Liquid supplement | 10.43 | 10.42 | 10.43 | 10.42 |
| Dry supplement, B-272[1] | 5.12 | 5.11 | - | - |
| Dry supplement, B-273[2] | - | - | 5.12 | 5.12 |

[1] 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 midds.

[2] 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 midds.

**Table 3.3.** Analyzed nutrient composition of diets fed

| | Experimental diet | | | |
|---|---|---|---|---|
| | NAT | | CONV | |
| Item[1] | LOW | HIGH | LOW | HIGH |
| 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/ton | - | - | 33.00 | 33.00 |
| Tylosin g/ton | - | - | 9.00 | 9.00 |

[1] All 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. Monensin and Tylosin values are formulated values.

**Table 3.4.** The effects of treatment on wheat pasture performance[1]

| Item | NAT | CONV | SE[2] | *P*-value<br>TRT |
|---|---|---|---|---|
| Total head | 90 | 90 | - | - |
| Days on wheat | 109 | 109 | - | - |
| Initial BW[3], kg | 250 | 250 | 19.13 | 0.97 |
| Final BW[3], kg | 366 | 385 | 11.98 | <0.01 |
| ADG, kg/d | 1.03 | 1.22 | 0.03 | <0.01 |

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

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

[3] No shrink was applied to BW; cattle were withheld from feed and water 12 h before weighing.

**Table 3.5.** The effects of treatment on initial and d 70 feedlot carcass ultrasound measurements

| | Production Program | | | Roughage Level | | | *P*-value | | |
|---|---|---|---|---|---|---|---|---|---|
| Item | NAT | CONV | SE[1] | LOW | HIGH | SE[1] | Interaction[2] | Program[3] | Roughage Level[4] |
| Pens | 16 | 16 | - | 16 | 16 | - | - | - | - |
| Total head | 80 | 80 | - | 80 | 80 | - | - | - | - |
| d 0 | | | | | | | | | |
| 12th rib-fat thickness, cm | 0.47 | 0.41 | 0.03 | 0.43 | 0.45 | 0.03 | 0.60 | <0.01 | <0.01 |
| REA, cm$^2$ | 66.60 | 68.15 | 2.01 | 67.49 | 67.25 | 2.01 | 0.96 | 0.09 | 0.79 |
| REA/BW ratio[5] | 1.26 | 1.22 | 0.04 | 1.24 | 1.23 | 0.04 | 0.92 | 0.04 | 0.60 |
| IMF[6], % | 3.86 | 3.59 | 0.07 | 3.73 | 3.72 | 0.07 | 0.34 | <0.01 | 0.63 |
| d 70 | | | | | | | | | |
| 12th rib-fat thickness, cm | 0.89 | 0.91 | 0.03 | 0.92 | 0.88 | 0.03 | 0.82 | 0.38 | 0.23 |
| REA, cm$^2$ | 82.50 | 88.57 | 1.14 | 85.75 | 85.32 | 1.14 | 0.47 | <0.01 | 0.68 |
| REA/BW ratio[5] | 1.16 | 1.12 | 0.04 | 1.14 | 1.14 | 0.04 | 0.18 | 0.02 | 0.91 |
| IMF[6], % | 4.39 | 4.11 | 0.07 | 4.23 | 4.27 | 0.07 | 0.48 | <0.01 | 0.56 |

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

[2] Program × roughage level interactions.

[3] Program examines the comparison of Natural (NAT) vs. Conventional (CONV).

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

[5] REA/BW ratio were calculated as REA/(BW/100).

[6] 2.0-3.9% = Slight 00-90; 4.0-5.5% = Small 00-90; 5.6-6.9% = Modest 00-90; 7.0-8.5% = Moderate 00-90.

**Table 3.6.** The effects of treatment on feedlot performance, deads and removals included[1]

| | Production Program | | | Roughage Level | | | *P*-value | | |
|---|---|---|---|---|---|---|---|---|---|
| Item | NAT | CONV | SE[2] | LOW | HIGH | SE[2] | Interaction[3] | Program[4] | Roughage Level[5] |
| Pens | 16 | 16 | - | 16 | 16 | - | - | - | - |
| Total head | 80 | 80 | - | 80 | 80 | - | - | - | - |
| Days on feed | 135 | 135 | - | 135 | 135 | - | - | - | - |
| Initial BW[6], kg | 373 | 394 | 25.57 | 383 | 383 | 25.57 | 0.90 | <0.01 | 0.78 |
| d 70 BW[6], kg | 488 | 517 | 3.23 | 503 | 503 | 3.10 | 0.17 | <0.01 | 0.93 |
| d 112 BW[6], kg | 535 | 594 | 25.28 | 564 | 564 | 25.28 | 0.54 | <0.01 | 0.89 |
| Final BW[6], kg | 578 | 628 | 5.96 | 607 | 599 | 5.96 | 0.56 | <0.01 | 0.37 |
| d 0 to 69 | | | | | | | | | |
| DMI, kg/d | 10.70 | 10.96 | 0.09 | 10.81 | 10.86 | 0.09 | 0.56 | 0.06 | 0.66 |
| ADG, kg/d | 1.53 | 1.97 | 0.03 | 1.76 | 1.74 | 0.03 | 0.09 | <0.01 | 0.77 |
| G:F, kg/kg | 0.143 | 0.180 | 0.003 | 0.163 | 0.160 | 0.002 | 0.07 | <0.01 | 0.52 |
| d 70 to 111 | | | | | | | | | |
| DMI, kg/d | 12.26 | 12.43 | 0.88 | 12.11 | 12.58 | 0.78 | 0.38 | 0.86 | 0.03 |
| ADG, kg/d | 1.39 | 1.70 | 0.04 | 1.56 | 1.54 | 0.04 | 0.21 | <0.01 | 0.69 |
| G:F, kg/kg | 0.118 | 0.133 | 0.003 | 0.128 | 0.123 | 0.002 | 0.07 | <0.01 | 0.09 |
| d 112 to 135 | | | | | | | | | |
| DMI, kg/d | 11.00 | 11.86 | 0.49 | 11.22 | 11.65 | 0.49 | 0.91 | <0.01 | 0.17 |
| ADG, kg/d | 1.49 | 2.06 | 0.09 | 1.92 | 1.62 | 0.09 | 0.67 | <0.01 | 0.03 |
| G:F, kg/kg | 0.135 | 0.174 | 0.01 | 0.171 | 0.138 | 0.01 | 0.54 | <0.01 | <0.01 |
| d 0 to 135 | | | | | | | | | |
| DMI, kg/d | 11.01 | 11.77 | 0.43 | 11.28 | 11.51 | 0.43 | 0.51 | 0.01 | 0.13 |
| ADG, kg/d | 1.48 | 1.90 | 0.03 | 1.73 | 1.66 | 0.03 | 0.39 | <0.01 | 0.09 |
| G:F, kg/kg | 0.132 | 0.164 | 0.002 | 0.153 | 0.144 | 0.002 | 0.47 | <0.01 | <0.01 |

[1] Data were analyzed with deads (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] Standard error of the mean (n = 16).

[3] Program × roughage level interactions.

[4] Program examines the comparison of Natural (NAT) vs. Conventional (CONV).

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

[6] A pencil shrink of 4% was applied.

**Table 3.7.** The effects of treatment on cumulative feedlot performance[1]

| | Production Program | | | Roughage Level | | | P-value | | |
|---|---|---|---|---|---|---|---|---|---|
| Item | NAT | CONV | SE[2] | LOW | HIGH | SE[2] | Interaction[3] | Program[4] | Roughage Level[5] |
| Pens | 16 | 16 | - | 16 | 16 | - | - | - | - |
| Total head | 80 | 80 | - | 80 | 80 | - | - | - | - |
| Days on feed | 135 | 135 | - | 135 | 135 | - | - | - | - |
| 4% adjusted[6] | | | | | | | | | |
| Initial BW, kg | 373 | 394 | 25.57 | 383 | 383 | 25.57 | 0.90 | <0.01 | 0.78 |
| Final BW, kg | 578 | 628 | 5.96 | 607 | 599 | 5.72 | 0.56 | <0.01 | 0.37 |
| d 0-135 DMI, kg/d | 11.01 | 11.77 | 0.43 | 11.28 | 11.51 | 0.43 | 0.51 | 0.01 | 0.13 |
| d 0-135 ADG, kg/d | 1.48 | 1.90 | 0.03 | 1.73 | 1.66 | 0.03 | 0.39 | <0.01 | 0.09 |
| d 0-135 G/F, kg/kg | 0.132 | 0.164 | 0.002 | 0.153 | 0.144 | 0.002 | 0.47 | <0.01 | <0.01 |
| Carcass adjusted[7] | | | | | | | | | |
| Final BW, kg | 571 | 635 | 7.13 | 610 | 597 | 6.85 | 0.76 | <0.01 | 0.22 |
| ADG, kg/d | 1.42 | 1.97 | 0.03 | 1.75 | 1.64 | 0.03 | 0.65 | <0.01 | 0.03 |
| G:F, kg/kg | 0.127 | 0.169 | 0.002 | 0.155 | 0.142 | 0.003 | 0.80 | <0.01 | <0.01 |
| Carcass gain d 112-135[8] | | | | | | | | | |
| Pred. HCW, kg | 337 | 374 | 15.93 | 356 | 355 | 15.93 | 0.54 | <0.01 | 0.89 |
| ADG, kg/d | 0.97 | 1.73 | 0.08 | 1.52 | 1.19 | 0.08 | 0.86 | <0.01 | <0.01 |
| G:F, kg/kg | 0.089 | 0.146 | 0.009 | 0.135 | 0.101 | 0.009 | 0.93 | <0.01 | <0.01 |
| Carcass gain overall[9] | | | | | | | | | |
| Pred. dress, % | 57.92 | 58.56 | 0.77 | 58.24 | 58.23 | 0.77 | 0.90 | <0.01 | 0.78 |
| Pred. HCW, kg | 216 | 231 | 17.86 | 224 | 223 | 17.86 | 0.90 | <0.01 | 0.79 |
| ADG, kg/d | 1.06 | 1.36 | 0.03 | 1.24 | 1.18 | 0.03 | 0.74 | <0.01 | 0.18 |
| G:F, kg/kg | 0.097 | 0.115 | 0.006 | 0.110 | 0.102 | 0.006 | 0.87 | <0.01 | 0.03 |

[1] Data were analyzed with deads (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] Standard error of the mean (n = 16).

[3] Program × roughage level interactions.

[4] Program examines the comparison of Natural (NAT) vs. Conventional (CONV).

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

[6] A pencil shrink of 4% was applied.

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

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

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

**Table 3.8.** The effects of treatment on carcass characteristics

| | Production Program | | | Roughage Level | | | *P*-value | | |
|---|---|---|---|---|---|---|---|---|---|
| Item, | NAT | CONV | SE[2] | LOW | HIGH | SE[2] | Interaction[3] | Program[4] | Roughage Level[5] |
| Pens | 16 | 16 | - | 16 | 16 | - | - | - | - |
| Total head | 78 | 75 | - | 76 | 77 | - | - | - | - |
| Stun Weight[1], kg | 566 | 646 | 27.49 | 608 | 604 | 27.49 | 0.20 | <0.01 | 0.32 |
| Shrink[1], % | 5.16 | 5.05 | 0.42 | 5.32 | 4.89 | 0.42 | 0.92 | 0.67 | 0.10 |
| HCW, kg | 362 | 424 | 16.08 | 398 | 389 | 16.08 | 0.64 | <0.01 | 0.02 |
| Dressing percentage, % | 63.31 | 64.89 | 0.21 | 64.37 | 63.83 | 0.21 | 0.68 | <0.01 | 0.08 |
| 12th rib-fat thickness, cm. | 1.74 | 1.79 | 0.07 | 1.75 | 1.78 | 0.07 | 0.13 | 0.53 | 0.71 |
| LM area, cm$^2$ | 83.95 | 100.89 | 1.04 | 93.54 | 91.30 | 1.04 | 0.26 | <0.01 | 0.14 |
| LM/HCW Ratio[6] | 1.63 | 1.68 | 0.07 | 1.66 | 1.65 | 0.07 | 0.43 | 0.15 | 0.90 |
| USDA Yield Grade | 3.54 | 3.09 | 0.20 | 3.28 | 3.34 | 0.20 | 0.11 | <0.01 | 0.62 |
| Marbling Score[7] | 500 | 421 | 6.37 | 465 | 456 | 6.37 | 0.12 | <0.01 | 0.33 |
| USDA Quality Grade | | | | | | | | | |
| Premium Choice, % | 48.70 | 18.72 | - | 32.15 | 31.59 | - | 0.32 | <0.01 | 0.95 |
| Low Choice, % | 36.93 | 54.05 | - | 44.66 | 46.04 | - | 0.15 | 0.05 | 0.87 |
| ≥ Choice, % | 85.95 | 73.06 | - | 80.53 | 80.04 | - | 0.57 | 0.06 | 0.94 |
| Select, % | 14.05 | 26.94 | - | 19.47 | 19.96 | - | 0.57 | 0.06 | 0.94 |
| USDAYield Grade | | | | | | | | | |
| USDA YG 1, % | 5.13 | 5.48 | - | 3.73 | 7.49 | - | 0.35 | 0.93 | 0.32 |
| USDA YG 2, % | 17.58 | 37.52 | - | 27.00 | 25.73 | - | 0.48 | 0.01 | 0.97 |
| USDA YG 3, % | 48.69 | 44.56 | - | 52.54 | 40.78 | - | 0.61 | 0.62 | 0.15 |
| USDA YG 4-5, % | 25.36 | 9.32 | - | 13.95 | 17.73 | - | 0.08 | 0.02 | 0.66 |
| Liver Abscess | | | | | | | | | |
| A +, % | 20.03 | 4.72 | - | 14.85 | 6.64 | - | 0.70 | 0.02 | 0.18 |
| A, % | 16.14 | 5.4 | - | 6.46 | 13.75 | - | 0.19 | 0.06 | 0.19 |
| Total abscessed, % | 39.56 | 10.51 | - | 21.84 | 21.57 | - | 0.23 | <0.01 | 0.97 |
| A+, % of abscessed | 56.35 | 46.41 | - | 69.10 | 33.33 | - | 0.65 | 0.65 | 0.10 |
| A, % of abscessed | 43.65 | 53.59 | - | 30.90 | 66.67 | - | 0.65 | 0.65 | 0.10 |

[1] Stun weight was obtained immediately after animal was knocked unconscious, and shrink was calculated as ((Final BW-Stun Weight)/Final BW)*100.

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

[3] Program × roughage level interactions.

[4] Program examines the comparison of Natural (NAT) vs. Conventional (CONV).

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

[6] REA/HCW ratio were calculated as REA/(HCW/100).

[7] 400 = Small00, 500 = Modest00, 600 = Moderate00.

**Table 3.9.** The effects of treatment on calculated dietary energy values[1]

| | Production Program | | | Roughage Level | | | *P*-value | | |
|---|---|---|---|---|---|---|---|---|---|
| Item, | NAT | CONV | SE[2] | LOW | HIGH | SE[2] | Interaction[3] | Program[4] | Roughage Level[5] |
| Pens | 16 | 16 | - | 16 | 16 | - | - | - | - |
| Total head | 80 | 80 | - | 80 | 80 | - | - | - | - |
| Days on feed | 135 | 135 | - | 135 | 135 | - | - | - | - |
| d 0-70 $NE_m$, mcal/kg | 1.87 | 2.11 | 0.03 | 2.00 | 1.98 | 0.03 | 0.08 | <0.01 | 0.42 |
| d 70-112 $NE_m$, mcal/kg | 1.74 | 1.85 | 0.02 | 1.82 | 1.76 | 0.02 | 0.09 | <0.01 | 0.03 |
| d 112-135 $NE_m$, mcal/kg | 1.96 | 2.28 | 0.09 | 2.26 | 1.98 | 0.09 | 0.48 | <0.01 | <0.01 |
| Overall $NE_m$, mcal/kg | 1.77 | 1.96 | 0.03 | 1.90 | 1.83 | 0.03 | 0.60 | <0.01 | <0.01 |
| d 0-70 $NE_g$, mcal/kg | 1.23 | 1.44 | 0.03 | 1.35 | 1.33 | 0.03 | 0.08 | <0.01 | 0.42 |
| d 70-112 $NE_g$, mcal/kg | 1.11 | 1.21 | 0.02 | 1.19 | 1.13 | 0.02 | 0.09 | <0.01 | 0.03 |
| d 112-135 $NE_g$, mcal/kg | 1.31 | 1.59 | 0.08 | 1.57 | 1.33 | 0.08 | 0.48 | <0.01 | <0.01 |
| Overall $NE_g$, mcal/kg | 1.14 | 1.31 | 0.02 | 1.26 | 1.19 | 0.02 | 0.60 | <0.01 | <0.01 |

[1] Data were analyzed with deads (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. Calculated according to Zinn et al., 1992.

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

[3] Program × roughage level interactions.

[4] Program examines the comparison of Natural (NAT) vs. Conventional (CONV).

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

# CHAPTER IV

## EFFECTS OF BEEF PRODUCTION SYSTEM ON RETAIL MEAT ATTRIBUTES

**ABSTRACT**: The objective of this study was to evaluate conventional and natural production programs through annual pasture and finishing with 2 roughage levels on carcass characteristics and retail meat attributes. Beef steers (n = 180; initial BW = 250 ± 19.1 kg) were randomized to one of two treatments in the pasture phase. Steers were implanted with 40 mg of TBA, 8 mg estradiol, and 29 mg tylosin tartrate (Conventional; CONV) or received no implant (Natural; NAT). The 2 treatments grazed winter annual pasture for 109 d. Steers (160 steers; 5 steers/pen; 8 pens/trt) were assigned to a 2 x 2 factorial RCBD during finishing. The first factor was production program (NAT vs. CONV) and the second 7 vs. 12% roughage (DM basis; LOW vs. HIGH.) During finishing, CONV steers were given 120 mg of TBA, 25 mg estradiol and 29 mg tylosin tartrate, fed monensin and tylosin for the entire feeding period, and fed zilpaterol hydrochloride for the last 20 d of the trial. At harvest, 17-18 strip loins/treatment were collected for retail meat attribute analysis. Conventional steaks had increased slice shear values (21.27 vs. 18.00 kg; $P < 0.01$) and Warner-Bratzler shear force (3.89 vs. 3.41, kg; $P < 0.01$) compared with NAT steaks, resulting in lower initial tenderness and connective tissue scores in a trained taste panel (6.8 vs. 7.1 and 6.9 vs. 7.1, $P < 0.01$, respectively.) There was a production program x roughage level interaction for overall tenderness during the trained sensory panel ($P = 0.03$). The NAT-LOW steaks exhibited the greatest overall tenderness score, indicating it was the most tender, compared to the other three treatments (7.04 vs. 6.52; $P \leq 0.05$). Steaks from cattle fed CONV had higher moisture content (70.18 vs. 68.85%; $P < 0.01$), lower lipid content (4.63 vs.

6.22%; $P < 0.01$), higher protein (24.25 vs. 23.29%; $P < 0.01$), and higher ash content (1.19 vs. 1.12%; $P = 0.04$) than steaks from NAT cattle. Steaks from NAT cattle exhibited a greater percentage of MUFA (46.70 vs. 45.55%; $P = 0.01$) but a lesser percentage of PUFA (4.31 vs. 4.98%; $P < 0.01$) than steaks from CONV cattle. There was a greater proportion of MUFA for cattle fed LOW compared to HIGH (46.67 vs. 45.58%: $P = 0.02$) and a trend for an increase in omega-3 fatty acids for cattle fed HIGH compared to LOW (0.73 vs. 0.68%; $P = 0.09$). Data from this study would suggest that producing beef in a conventional manner using ionophores, antibiotics, implants and beta-agonists does not negatively impact beef quality and may have added benefits in comparison to production without the use of technology.

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

## INTRODUCTION

The United States Department of Agriculture defines “natural” as a product that “must be minimally processed and contain no artificial ingredients.” There are no regulations as to limiting or excluding the use of efficiency enhancing technologies or other management practices. Individual companies have developed their own natural programs and adhere to company specific guidelines for programs (raised without growth hormones, ionophores, beta-agonists, etc.). Due to marketing claims, consumers believe that a product defined or labeled as “natural” possesses superior qualities and human-health attributes as compared to conventionally produced beef. A 2013 consumer survey, *“Power of Meat”* found that 26% of all respondents had purchased organic/natural meat within 3 months of the survey, up from 18% in 2009, with the top reason for purchasing natural or organic meat at 55% is the belief of a positive long-term personal health effect. Interestingly, a new term for the 2013 survey was the second reason with 46% of the respondents saying it is free of substances they want to avoid.

Previously published data in regards to beef production mostly deals with the difference in grain-fed vs. grass-fed beef. Reviews from Daley et al. (2010) and Van Elswyk and McNeill

(2014) clearly show that grass-fed beef contains lower fat concentrations mostly with lowered MUFA concentrations than grain-fed beef. However, few long-term human health studies have defined the benefits of either type of beef, suggesting both can play a positive role in meeting nutrient requirements of humans. Moreover, data is limited examining the effects of conventional beef production (growth-implants, ionophores, beta-agonists, etc.) compared to production without these technologies (Natural) on retail meat attributes and nutritional quality. Therefore the objective of this study was to determine the effects of conventional and natural beef production on measurements of tenderness, trained sensory analysis, retail shelf-life, and nutritional composition.

## MATERIALS AND METHODS

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

### *Cattle Management and Study Treatments*

Black-hided yearling steers (n = 180) from a single ranch in western Oklahoma were used for this study. Prior to the initiation of this experiment, animals had been managed in a way to insure that all animals would qualify for an All-Natural program at harvest. At initiation of the experiment, steers were weighed and allocated to one of 2 treatments for the grazing phase. Steers were either administered an implant containing 40 mg/steer trenbolone acetate, 8 mg estradiol and 29 mg tylosin tartrate (**CONV**; Component TE-G; Elanco Animal Health, Greenfield, IN) or received no-implant (**NAT**). The steers were allowed to graze annual cool season forage for 109 d. After the grazing period, the steers were transported to the Willard Sparks Beef Research Center (Oklahoma State University, Stillwater OK) for the finishing phase of the experiment. Of the original 180 steers, 160 steers were used in the finishing study. Steers with noted abnormalities (abscess, lameness, or BW extremes) were removed. The steers were allocated to a 2 x 2 factorial randomized complete block design (2 weight blocks; 4 replications/block; 8 pens/treatment; 5 steers/pen; 40 steers/treatment). The first factor was production program, either CONV or NAT, and the second was roughage level (7% diet DM [**LOW**] or 12% diet DM [**HIGH**]). The animals that were implanted during the grazing phase remained CONV steers, and those not receiving an implant remained designated to NAT. During the feedlot phase, the CONV animals were implanted with 120 mg TBA, 24 mg estradiol and 29 mg tylosin tartrate (Component TE-S w/ Tylan, Elanco Animal Health). The CONV steers were also fed 33 mg/kg of monensin, 9 mg/kg of tylosin throughout the feeding period with 90 $mg \cdot steer^{-1} \cdot d^{-1}$ zilpaterol hydrochloride (Zilmax; Merck Animal Health, DeSoto, KS) for the last 20 d followed by a 3 d withdrawal. The NAT animals received no growth implants, ionophores, antibiotics or beta-agonist. All cattle were fed for 135 d and slaughtered at Creekstone Farms, Arkansas City, KS. Additional information regarding the feeding, management and performance results were reported by Maxwell et al. (2014).

### *Carcass Evaluation and Strip Loin Selection*

Due to requirements of the packing facility, the CONV cattle were slaughtered on d 135 (Jul 26, 2012), whereas the NAT cattle were slaughtered on d 136 (Jul 27, 2012). This difference in slaughter date was due to the facility only slaughtering NAT cattle on Fridays of each week. This difference also caused a difference in chill time for each treatment group. The CONV cattle where graded and fabricated 120 h post-harvest (Jul 31, 2012), whereas the NAT cattle were graded and fabricated 72 h post-harvest (Jul 30, 2012). At grading, 72 carcasses (18 carcasses/treatment) were selected for retail meat analysis. Carcass were selected such that each block and treatment was equally represented. Each carcass was evaluated and selected to insure that the marbling score was in the range of USDA Choice (400-690). Actual marbling scores for each treatment are shown in Table 4.3. There were 2 carcass selected in NAT-LOW that had marbling scores of 380 and 310. Due to missing one loin on the fabrication line, there were only 17 loins obtained for CONV-HIGH and 18 loins collected for the other 3 treatments. Strip loins (n = 71; Institutional Meat Purchase Specifications [**IMPS**] #180) were collected from the fabrication line at Creekstone Farms and transported to the Oklahoma State University Food and Agricultural Products Center (**FAPC**). Upon arrival at FAPC strip loins were stored at 4°C until fabrication. On Aug 9, 2012, the strip loins were fabricated into six, 2.54 cm steaks, (14 d postmortem for CONV and 13 d postmortem for NAT). Fabrication began at the most anterior end, and the first steak was removed to level the face of the strip loin and this steak was designated for fatty acid composition and proximate analysis. The second steak was designated for retail display analysis, and then the 3rd -5th steak were used for Warner-Bratzler shear force (**WBSF**), slice shear force (**SSF**), trained sensory panel, and the last steak was saved for an extra. All steaks except for the steak designated for retail display analysis were vacuum-packaged and frozen at -28°C immediately post fabrication until analysis. At fabrication, each loin was assigned a number 1-71. This number was assigned to all steaks to insure all analysis was blinded.

### ***Retail Display Analysis***

For retail display analysis, each steak was placed in a 23.5 x 18.4 x 1.6 cm white foam tray (No. 42, Cryovac Sealed Air) with Cryovac absorbent pads and over-wrapped with polyvinyl chloride (PVC) film. All 71 steaks were placed in the retail case equipped with Promolux low UV lights (Atlanta Light Bupound Co., Atlanta, GA) and monitored daily for muscle color, surface discoloration and overall acceptability. Temperature on the retail case was set to 0°C, with the defrost cycle occurring every 7 h for 1 h. Steaks were rotated throughout the case, top to bottom and left to right every 24 h. Steaks were visually evaluated by a 6-9 member trained color panel every 24 h. Overall appearance was evaluated on a 8-point scale (1 = extremely undesirable, 4 = slightly desirable, and 8 = extremely desirable), surface discoloration was evaluated on a 7 point scale (1 = no discoloration [0%], 4 = modest discoloration [40-59%], and 7 = total discoloration [100%]), and muscle color was evaluated on an 8-point scale (1 = extremely dark red, 4 = slight dark cherry red, and 8 = extremely bright cherry red). The steaks were evaluated for 7 d.

### ***Slice Shear Force Analysis***

On August 28, 2012, the steaks designated for SSF were removed from the freezer and placed in a cooler for 24 h and allowed to thaw to 2 to 5°C. Once thawed, the steaks were cooked to an internal temperature of 69-71°C using an impingement oven at 180 °C (Lincoln Impinger, Model 1132-00-A, Lincoln Foodservice Products, Fort Wayne, IN) on August 29, 2012. Once cooked, the steaks were trimmed to square the steak and expose the muscle fibers. Using the methods of Shackelford et al. (1999) as described by Price et al. (2008), a section of cooked steak was removed for analysis. After the section was obtained, SSF was measured using an Instron Universal Testing Machine (Model 4502, Instron Corporation, Canton, MS). The slice shear attachment moved at a speed of 500 mm/min. Max slice shear force values were obtained in kilograms.

### ***Warner-Bratzler Shear Force Analysis***

Also, on August 28, 2012, the steaks designated for WBSF analysis were thawed and then cooked in the same method as mentioned for SSF on August 29, 2012. These steaks were then placed in a cooler at 4°C and allowed to cool until the next day. Prior to WBSF analysis, the steaks were removed from the cooler and allowed to reach room temperature. Steaks were then cored (6 cores/steak) parallel to the muscle fibers. Each core was sheared using the WBSF head on the Instron machine, which moved at 200 mm/min, and the mean peak load was obtained for each steak by averaging peak load of all 6 cores.

### ***Trained Sensory Panel***

Beginning on December 2, 2012, for 6 consecutive days, the trained sensory panel was completed. Each day 11-12 samples/session were evaluated by a 6-8 member trained sensory panel. The steaks were thawed and cooked in the same manner as the SSF and WBSF procedures. After cooking, steaks were cut into individual servings and immediately served. The panelists evaluated and scored each sample for initial and sustained juiciness on an 8-point scale (1 = extremely dry, 4 = slightly dry, and 8 = extremely juicy), first and overall impression tenderness on a 8 point scale (1 = extremely tough, 4 = slightly tough, and 8 = extremely tender), overall connective tissue amount on an 8-point scale (1 = abundant, 4 = moderate, and 8 = none), cooked beef flavor on a 15-point scale (5 = beef broth, 7 = ground beef, and 11 = beef brisket), metallic flavor on a 15-point scale ( 4 = strip steak, and 6 = pineapple juice), and rancidity on a 15-point scale (vegetable oil warmed for 3 minutes = 7, and vegetable oil warmed for 5 minutes = 9), and green haylike flavor on a 15-point scale (6 = parsley). The scores were averaged across all panelists for analysis.

### ***Proximate Analysis and Fatty Acid Composition Analysis***

For fatty acid, proximate analysis, cholesterol analysis and mineral analysis, frozen samples were shipped to Iowa State University (Ames, IA) for analysis. Prior to analysis, steaks were trimmed of external fat and the *Longissiums dorsi* muscle was ground to a fine powder. Lipid extraction was done using the Wet Tissue Lipid Extraction method using chloroform and methanol extraction described by Folch et al. (1957) and Buchanan et al. (2013). Esterification was done by adding acetyl chloride and methanol according to Christi (1972). Fatty acid concentrations were then analyzed using gas chromatography (model 3800, Varian Analytical

Instruments, Walnut Creek, CA) with a 100 m column (model SP-2380, Supelco, Bellefonte, PA). Peak analysis was obtained by using the software Star Chromotography Workstation Version 5.52 (Walnut Creek, CA). Individual fatty acids were calculated as a percentage of total fatty acids in the total lipid extracted from muscle tissue. Individual fatty acids were used to calculate total percentage of omega 3, and omega 6 PUFA, SFA, MUFA, and PUFA, similar to the calculations done by (Buchanan et al., 2013). Lastly, the atherogenic index was determined as described by Ulbricht and Southgate (1991).

Proximate analysis was performed on the samples to determine percent moisture, protein, and fat according to Association of Official Analytical Chemists (AOAC) methods. Protein was determined by combustion using the LECO TruMac (St. Joseph, MI), moisture was determine by oven drying, lipid was determined as described above (Folch et al., 1957), and ash was determined by placing samples in a muffle furnace at 600°C for 4 hr. Cholesterol content was analyzed by using the cholesterol oxidase kit (Pointe Scientific, Canton, MI), and expressed as mg/100 g of wet tissue. Individual mineral analysis was determined by using inductively coupled plasma optical emission spectrometry (Optima 7000 DV, Perkin Elmer, Waltham, MA) as described by Pogge et al. (2014). Individual mineral concentration was expressed on an mg/100 g wet tissue basis.

### ***Statistical Analysis***

All data were analyzed using PROC MIXED (SAS 9.3; SAS Inst. Cary, NC). Individual steak was used as the experimental unit, and weight block was included as a random effect. All production system x roughage level interactions were considered different and means were separated using Tukey adjustment method when $P < 0.05$. All means were considered statistically significant when $P < 0.05$, and a trend when $0.05 < P < 0.10$.

## RESULTS

### *Shear Force and Trained Sensory Analysis*

There was no production program x roughage level interaction in regards to shear force (Table 4.1; $P \geq 0.60$). Warner-Bratzler shear force was increased 0.48 kg for CONV steaks compared to NAT steaks (3.89 vs. 3.41 kg; $P < 0.01$). Similarly SSF was increased by 3.27 kg for CONV steaks compared to NAT steaks (21.27 vs. 18.00 kg; $P < 0.01$). There was no effect of roughage level on WBSF or SSF ($P \geq 0.27$).

Results from the trained sensory panel showed there was a trend for a decrease in initial juiciness for CONV steaks compared to NAT steaks (6.88 vs. 7.09; $P = 0.06$) and a decrease in sustained juiciness for CONV steaks compared to NAT steaks (6.45 vs. 6.70; $P = 0.05$). Steaks from cattle fed NAT were considered to have a more desirable initial tenderness rating compared to CONV steaks (7.10 vs. 6.79; $P < 0.01$). Moreover, there was a trend for steaks from the cattle fed LOW to have a more desirable initial tenderness rating compared to HIGH steaks (7.02 vs. 6.87; $P = 0.07$). There was a production program x roughage level interaction for overall tenderness during the trained sensory panel ($P = 0.03$). Steaks from the NAT-LOW exhibited the greatest overall tenderness score indicating it was the most tender compared with steaks from the other three treatments (7.04 vs. 6.52; $P \leq 0.05$). However, there were no differences noted in overall tenderness for the other three treatments (NAT-HIGH, CONV-LOW, and CONV-HIGH). Similar to initial tenderness, there was a decrease in the score for connective tissue noted for CONV steaks compared to NAT steaks (6.85 vs. 7.06; $P < 0.01$), indicating a greater amount of connective tissue present. There were no differences noted in cooked-beef flavor, metallic flavor, rancid flavor or hay-like flavor across the treatments ($P \geq 0.12$).

### *Retail Display Analysis*

Table 4.2 shows the effects of treatment on retail display analysis. At h 0, there was a statistically significant ($P = 0.04$) difference in muscle color and overall appearance for NAT steaks compared to CONV steaks. However, the differences were very small, (< 0.05 of a scoring unit) and deemed irrelevant. There was a trend for steaks from the HIGH cattle to have a lower, less desirable muscle color than steaks from LOW at h 168. (3.23 vs. 3.58; $P = 0.07$). There were no other differences noted in muscle color, surface discoloration, or overall appearance throughout the 7 d the steaks were evaluated ($P \geq 0.11$).

### ***Proximate Analysis, Fatty Acid Composition and Mineral Analysis***

The effects of treatment on proximate analysis is shown in Table 4.3. There were no production program x roughage level interactions noted for any of the proximate analysis, fatty acid composition or mineral analysis data ($P > 0.10$). Steaks from cattle fed CONV had greater moisture content (70.18 vs. 68.85%; $P < 0.01$) lower lipid content (4.63 vs. 6.22%; $P < 0.01$), greater protein (24.25 vs. 23.29%; $P < 0.01$), and greater ash content (1.19 vs. 1.12%; $P = 0.04$) than steaks from NAT cattle. There were no differences noted in total cholesterol (mg/100 g, wet tissue) between production programs. There was a trend for a greater lipid content (5.70 vs. 5.14%; P = 0.10) for steaks from cattle fed LOW compared to the steak from the cattle fed HIGH. The greater ash content in the steaks from the CONV cattle is due to the greater, sodium, phosphorus, and magnesium ($P < 0.05$) concentrations found compared to steaks from the NAT cattle (Table 4.4). The steaks from the cattle fed NAT contained a greater amount of copper and iron compared to the steaks from the CONV cattle ($P < 0.01$). There was no effect of roughage level on individual mineral content of steaks ($P \geq 0.11$).

The effect of production program and roughage level on fatty acid component of strip loin steaks is shown in Table 4.5. There were no production program x roughage level interactions noted on fatty acid composition ($P > 0.10$). There was no difference in total SFA content between NAT and CONV (46.73 vs. 47.09%; $P = 0.46$). However, steaks from NAT cattle exhibited a greater amount of MUFA (46.70 vs. 45.55%; $P = 0.01$), but a lesser amount of PUFA (4.31 vs. 4.98%; $P < 0.01$) than steaks from CONV cattle. There was no difference between omega-3 fatty acids in steaks from CONV or NAT cattle (0.69 vs. 0.72%; $P = 0.29$), but omega-6 fatty acids were greater in steaks from CONV cattle compared to steaks from NAT cattle (4.11 vs. 3.43%; $P < 0.01$). In regards to SFA, steaks from NAT cattle had greater concentrations of palmitic acid (16:0; 27.20 vs. 26.04%; $P < 0.01$) and a trend for a greater percentage of pentadecanoic acid (15:0; 0.34 vs. 0.32; $P = 0.07$) and margaric acid (17:0; 1.06 vs. 1.01; $P = 0.09$). However, steaks from CONV cattle possessed a greater amount of stearic acid (18:0; 17.05 vs. 15.29%; $P < 0.01$). For MUFA, steaks from NAT cattle had greater concentrations of palmitoleic acid (16:1; 3.07 vs. 2.83%; $P = 0.03$), oleic acid (18:1; 38.76 vs. 37.60%; $P = 0.01$), and trend for an increase in heptadecenoic acid (17:1; 0.70 vs. 0.66%; $P = 0.10$). Steaks from CONV cattle exhibited a greater amount of trans vaccenic acid (TVA 18:1 t11, t10; 2.78 vs. 2.28%; $P < 0.01$), linoleic acid (18:2; 3.80 vs. 3.05%; $P < 0.01$), and docosapentaenoic acid (DPA – 3; 22:5; 0.25 vs 0.21%; $P = 0.03$) compared to steaks from NAT cattle. Lastly, steaks from NAT cattle exhibited greater amounts of eicosadienoic acid (20:2; 0.08 vs. 0.05%; $P = 0.02$), arachidonic acid (20:4; 0.06 vs. 0.04%; $P < 0.01$), and adrenic acid (22:4 0.06 vs. 0.04%; $P < 0.01$) compared to those from NAT cattle. There was a slight increase in the PUFA:SFA ratio for steaks from CONV cattle compared to steaks from NAT cattle (0.11 vs. 0.09; $P < 0.01$), however, the MUFA:SFA ratio tended to be greater for steaks from NAT cattle compared to CONV cattle (1.00 vs. 0.97; $P = 0.09$). There was no difference amongst production programs in regards to omega-6:omega-3 ratio or atherogenic index ($P \geq 0.14$).

In regards to roughage level, there was a greater proportion of MUFA for cattle fed LOW compared to HIGH (46.67 vs. 45.58%: $P = 0.02$) and a trend for an increase in omega-3 fatty acids for cattle fed HIGH compared to LOW (0.73 vs. 0.68%; $P = 0.09$). For SFA, steaks from cattle fed LOW had greater amounts of pentadecanoic acid (15:0; 0.35 vs. 0.30%; $P < 0.01$), and margaric acid (17:0; 1.14 vs. 0.93%; $P < 0.01$) compared to steaks from HIGH cattle. There was a trend for an increase in palmitic acid for steaks from cattle fed HIGH compared to steaks from cattle fed LOW (16:0; 26.95 vs. 26.30%; $P = 0.07$). For MUFA, steaks from cattle fed LOW had increased amounts of heptadecenoic acid (17:1; 0.75 vs. 0.61%; $P < 0.01$) and oleic acid (18:1; 38.70 vs. 37.65%; $P = 0.02$), resulting in a greater MUFA:SFA ratio (1.01 vs. 0.97; $P = 0.04$) compared to steaks from cattle fed HIGH. There was no effect of roughage level on omega-6:omega-3 ratio ($P = 0.86$). However, steaks from cattle fed HIGH had a trend for an increased atherogenic index (0.75 vs. 0.72: $P = 0.09$) compared to steaks from cattle fed LOW.

## DISCUSSION

The effects of conventional and natural beef production systems on retail meat attributes have not been heavily studied, with very little published research data. Most studies have examined the differences between conventional and organic/grass-fed systems or differences across different technologies. Data from several studies show that the feeding of Zilmax increases WBSF and SSF values of steaks aged 14 d. Similar to the results of the current study, Rathmann et al. (2012) showed a 0.52 kg increase in WBSF and a 2.29 increase in SSF for cattle fed Zilmax compared to controls. Bloomberg et al. (2013) noted a 0.45 kg increase in WBSF for steaks from heifers fed Zilmax compared to control, however, no differences were noted in juiciness or tenderness in a trained sensory panel. Additionally, Garmyn et al. (2011) showed a 1.17 kg increase in WBSF and a 5.64 kg increase in SSF for cattle fed Zilmax compared to controls after a 14 d aging period. Interestingly, Garmyn et al. (2011) noted a 0.41 kg increase in WBSF for cattle receiving either a Revalor –S or Revalor-XS implant compared to a non-implanted control. However, this difference was not noted in SSF values. Furthermore, the implant x Zilmax interaction was not significant, indicating that the effects of implants and Zilmax on shear force values are not additive. Platter et al. (2003) showed a 0.41 kg increase in WBSF for cattle implanted twice in feedlot phase compared to non-implanted controls after a 14 d aging period. Hilton et al. (2009) examined the effects of Zilmax in combination with monensin and tylosin on retail meat attributes. There was no effect of monensin/tylosin supplementation on WBSF, however, Zilmax supplementation increased WBSF by 0.40 kg compared to a non-supplemented control. Similar to the results of the current study, in a trained sensory panel, the panelists determined that steaks from cattle fed Zilmax exhibited a less desirable juiciness and tenderness score (Hilton et al., 2009). Interestingly, in a consumer panel, panelists determined that steaks from cattle fed Zilmax were less tender than the controls, however, there was no difference noted in juiciness, flavor, or overall acceptability (Hilton et al., 2009). Walshe et al. (2006) indicated no differences between conventional and organic beef in a sensory panel. However, no description was given of the treatments, and since the study was completed in Ireland, it is suspected no growth-technologies were used. Platter et al. (2003) performed a consumer panel comparing implanted beef to non-implanted beef. The consumers noted a decrease in tenderness and juiciness for implanted beef compared to non-implanted beef. However, overall eating satisfaction was not different due to implants (Platter et al., 2003). At 14 d of aging, Igo et al. (2011) noted a 1.5 kg increase in SSF, with no differences in WBSF for cattle receiving either a REV-IS/S or Revalor-XS implant compared to a non-implanted control. Consumers found no differences in tenderness or juiciness resulting in similar overall acceptability and tenderness acceptability across treatments in USDA Choice Steaks (Igo et al., 2011). Consumers, were able to determine the differences in USDA Select steaks aged 14 d, however the differences were much smaller at 21 d of aging (Igo et al., 2011). Similar results were published by Roeber et al. (2000), who noted a 0.34 kg increase in WBSF for cattle given (Ralgro and Revalor-S) compared to a non-implanted control. Consumers were able to determine the differences in tenderness between the two treatments, however, there was no difference in overall like/dislike level between the treatments. Garmyn and Miller (2014) reviewed several studies examining the differences in WBSF due to implants and Zilmax. Using the data presented in that review across 7 trials (1,795 animals), the average difference in WBSF between two combination implants and a non-implanted control (similar implant strategy to the current study), was 0.36 kg. Similar to the results of this study, previously published literature would confirm that the use of implants and beta-agonists do increase WBSF and SSF values, indicating a decrease in tenderness. Trained sensory panels are able to determine these differences; however, results from consumer panels indicate that consumers are unable to distinguish a difference in the products, and indicate steaks from cattle produced using implants and beta-agonists as acceptable.

Results from the current study indicate no differences in length of retail shelf life between steaks from NAT and CONV. These results are similar to those discussed by Bloomberg et al. (2013) and VanOverbeke et al. (2009) who noted no effect of Zilmax supplementation for 20 d on color scores of gluteus medius in PVC packaging compared to controls. Moreover, Luque et al. (2011) noted no differences in retail shelf life on ground beef samples from Zilmax supplemented or control cattle.

There has been a great deal of research conducted examining the human health implications of grass-fed vs. organic vs. conventional beef production with very little data pertaining to natural and conventional beef production. Proximate analysis values, cholesterol, and mineral concentration for strip loin steaks presented in this study are similar to other published data for conventional beef (Leheska et al., 2008; Duckett et al., 2009; Hilton et al. 2009; Duckett et al., 2013). As expected based upon carcass characteristics, overall protein was increased and fat decreased in the strip-loin. These results are similar to those published by Sheffler et al. (2003) who noted an increase in protein content of the *Longissimus* muscle of Holstein steers when administered an implant compared to non-implanted controls. However, unlike our study, there were no effects of implant on fat content or moisture content. Similarly, Hilton et al. (2009) noted a decrease in *Longissimus* fat content with a numerical increase in protein with no effect on moisture for cattle fed Zilmax compared to controls. Moreover, Shook et al. (2009) reported a numerical increase in fat and an increase in protein in strip loin steaks for cattle fed Zilmax compared to controls. Even though the steaks from NAT cattle contained a greater amount of lipid compared to steaks from CONV cattle, cholesterol concentration did not differ. This is similar to results from Leheska et al. (2008) and Duckett et al. (2009) who observed a drastic increase in fat content for grain-fed cattle compared to grass-fed cattle, but no shift in cholesterol content. Daley et al. (2010) described that as marbling increases cholesterol expressed per gram of tissue increases. However, that was not noted in this study. Recall, that the steaks were selected such that they would grade as USDA Choice, but marbling score was slightly higher for the NAT cattle compared to the CONV cattle. Previously published data suggests that, as lipid content in beef increases, moisture decreases similar to the results presented in this study (Duckett et al., 1993, Leheska et al., 2008, and Duckett et al., 2009). Also in the current study, coupled with the decrease in lipid is an increase in muscle protein. Hilton et al. (2009) noted a numerical increase in moisture content of *Longissmius* muscle and a significant increase in carcass moisture for cattle fed Zilmax compared to controls. There is little data available to compare the mineral content of the steaks. However, due to an increase in DMI, it is hypothesized that this is the main driver for the increased mineral content of the CONV cattle. Duckett et al. (1993) showed that as cattle get fatter, iron levels increased. That would explain the iron differences between the two production programs, as the NAT cattle contained an increased amount of intramuscular lipid, even though 12th rib-fat thickness was equal across treatments.

Similar to data published by Webb and Casey (1995), oleic acid (18:1) was the most abundant fatty acid in both treatments, palmitic acid (16:0) was the 2nd most abundant, and stearic acid (18:0) 3rd most abundant. The proportion of SFA to MUFA was approximately 1 with both comprising about 46% of all fatty acids, similar to Webb and Casey (1995) and Leheska et al. (2008). Daley et al. (2010) outlined that myristic (14:0) and palmitic SFA (16:0) are most detrimental to overall cholesterol levels, whereas stearic acid (18:0) has a neutral impact on overall cholesterol. Results from the current study are similar to the results of Webb and Casey (1995), where cattle administered a combination implant and fed a beta-agonist has no difference in myristic acid, but had lower palmitic and higher stearic acid levels compared to a control. Fritsche et al. (2001) reported that administration of Revalor-S, decreased myristic, and increased stearic acid with no differences in palmitic acid. Faucitano et al. (2008) published that the use of growth promotants increased margaric and oleic acid. In contrast to the results of this study, Webb and Casey (1995) noted that cattle given an implant and fed beta-agonist had similar oleic acid (18:1) content as control. Moreover, Fritsche et al. (2001) reported no difference in oleic acid for implanted cattle compared to a non-implanted control. However, Webb and Casey (1995) noted that the cattle given only a beta-agonist and no implant had higher oleic acid content than the control. The results of this study showed the opposite effect as the NAT cattle had higher oleic acid content than CONV. Data from Leheska et al. (2008), Daley et al. (2010), and Buchanan et al. (2013) suggests that grain-fed conventional beef most often contains more oleic acid than grass-fed beef. Daley et al. (2010) discussed the importance of trans-vaccenic acid (18:1, t11) and its role in the synthesis of conjugated-linoleic acid (18:2, c-9, t-11), an essential fatty acid, as an anti-carcinogenic. Interestingly in the current study, vaccenic acid was of greater proportion in the CONV cattle as compared to the NAT cattle. Similar to the current study, Fritsche et al. (2001) noted a numerically higher linoleic content in intramuscular fat for cattle given Revalor-S compared to a control. However, Webb and Casey (1995) noted no differences between cattle implanted combined with the feeding of a beta-agonist compared to a negative control. Moreover in the current study, linoleic acid, an essential fatty acid, was higher in CONV than NAT. Faucitano et al. (2008) noted similar results to the current study and with an increase in *trans* 18:1 suggested that monensin interferes with biohydrogenation and may lead to an increase in *trans* 18:1. Daley et al. (2010) discussed the importance of the omega-6:omega-3 ratio, and data suggests that omega-6 content of grass-fed and grain-fed beef are similar. However, grass-fed beef contains a great deal more omega-3 fatty acid, creating a lower, more favorable omega-6:omega-3 ratio. Results from this study suggest that CONV cattle have more omega-6 fatty acids. However with a numerically higher omega-3 content, the omega–6:omega-3 ratio is not different across treatments. In this study, the long chain fatty acids were fairly low in proportion, and the differences are hypothesized to not be of biological importance. Similar to data published by Jenschke et al. (2008) and Sami et al. (2012), there was little effect of roughage level to any of the parameters in this study.

## CONCLUSIONS

Data from this study would suggest that producing beef in a conventional manner using ionophores, antibiotics, implants and beta-agonists does not negatively impact beef quality and may have added benefits in comparison to production without the use of technology. There is a decrease in overall tenderness of beef, however results suggest this decrease is not large enough to effect overall consumer acceptability. Retail-shelf life is unaffected by production program. The use of technologies increases protein content and decreases fat content of *Longissmius dorsi*, which becomes important to those concerned with decreasing overall fat content. More research is needed to determine the extent to which efficiency enhancing technology alters fatty acid composition, proximate analysis, and mineral composition. However this data suggests there may be an increase in some of the important fatty acids and minerals in regards to human health. However it is unknown how big the change must be to be biologically relevant to human nutrition.

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**Table 4.1.** The effects of treatment on trained taste panel attributes and shear force values

| | NAT | | CONV | | | *P*-value | | |
|---|---|---|---|---|---|---|---|---|
| Item | LOW | HIGH | LOW | HIGH | SE[8] | Interaction[9] | Program[10] | Roughage Level[11] |
| n | 18 | 18 | 18 | 17 | - | - | - | - |
| Initial juiciness[1] | 7.16 | 7.02 | 6.89 | 6.87 | 0.17 | 0.60 | 0.06 | 0.43 |
| Sustained juiciness[1] | 6.82 | 6.57 | 6.43 | 6.47 | 0.16 | 0.23 | 0.05 | 0.37 |
| Initial tenderness[2] | 7.23 | 6.97 | 6.81 | 6.76 | 0.11 | 0.23 | <0.01 | 0.07 |
| Overall tenderness[2] | $7.04^{a}$ | $6.64^{b}$ | $6.48^{b}$ | $6.46^{b}$ | 0.09 | 0.03 | <0.01 | 0.02 |
| Connective tissue[3] | 7.12 | 6.99 | 6.85 | 6.84 | 0.07 | 0.43 | <0.01 | 0.30 |
| Cooked-beef flavor[4] | 7.12 | 7.06 | 7.01 | 7.00 | 0.14 | 0.63 | 0.12 | 0.44 |
| Metallic flavor[5] | 4.19 | 4.22 | 4.15 | 4.22 | 0.06 | 0.66 | 0.72 | 0.28 |
| Rancid flavor[6] | 1.64 | 1.56 | 1.48 | 1.46 | 0.14 | 0.72 | 0.13 | 0.53 |
| Hay-like flavor[7] | 1.15 | 1.13 | 1.11 | 1.14 | 0.08 | 0.63 | 0.74 | 0.86 |
| Slice shear, kg | 17.84 | 18.16 | 21.56 | 20.97 | 1.12 | 0.60 | <0.01 | 0.88 |
| Warner-Bratzler shear, kg | 3.31 | 3.50 | 3.84 | 3.94 | 0.13 | 0.74 | <0.01 | 0.27 |

[a,b] Means without a common superscript differ ($P \le 0.05$).

[1] 1 = extremely dry; 2 = very dry; 3 = moderately dry; 4 = slightly dry; 5 = slightly juicy; 6 = moderately juicy; 7 = very juicy; 8 = extremely juicy.

[2] 1 = extremely tough; 2 = very tough; 3 = moderately tough; 4 = slightly tough; 5 = slightly tender; 6 = moderately tender; 7 = very tender; 8 = extremely tender.

[3] 1 = abundant; 2 = moderately abundant; 3 = slightly abundant; 4 = moderate; 5 = slight; 6 = traces; 7 = practically none; 8 = none.

[4] 1 – 15 scale; 11 = brisket; 7 = ground beef; 5 = beef broth.

[5] 1 – 15 scale; 4 = strip loin steak; 6 = pineapple juice.

[6] 1 – 15 scale; 7 = vegetable oil warmed 3 min; 9 = vegetable oil warmed 5 min.

[7] 1 – 15 scale; 6 = parsley.

[8] Standard error of the mean (n = 17 or 18).

[9] Program × roughage level interactions.

[10] Program examines the comparison of Natural (NAT) vs. Conventional (CONV).

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

**Table 4.2.** The effects of treatment on retail display attributes

| | NAT | | CONV | | | *P*-value | | |
|---|---|---|---|---|---|---|---|---|
| Item | LOW | HIGH | LOW | HIGH | SE[1] | Interaction[2] | Program[3] | Roughage Level[4] |
| n | 18 | 18 | 18 | 17 | - | - | - | - |
| Muscle color[5] | | | | | | | | |
| 0 h | 7.95 | 7.97 | 7.93 | 7.88 | 0.03 | 0.22 | 0.04 | 0.45 |
| 168 h | 3.49 | 3.40 | 3.62 | 3.06 | 0.18 | 0.18 | 0.56 | 0.07 |
| 0-168 h | 6.53 | 6.52 | 6.62 | 6.45 | 0.08 | 0.31 | 0.93 | 0.22 |
| Surface discoloration [6] | | | | | | | | |
| 0 h | 1.00 | 1.00 | 1.00 | 1.00 | - | - | - | - |
| 168 h | 3.60 | 3.93 | 3.56 | 4.03 | 0.34 | 0.84 | 0.92 | 0.24 |
| 0-168 h | 1.61 | 1.69 | 1.56 | 1.77 | 0.09 | 0.45 | 0.86 | 0.11 |
| Overall appearance[7] | | | | | | | | |
| 0 h | 8.00 | 7.99 | 7.99 | 7.98 | 0.006 | 0.95 | 0.04 | 0.20 |
| 168 h | 2.51 | 2.37 | 2.49 | 2.44 | 0.22 | 0.83 | 0.90 | 0.67 |
| 0-168 h | 6.47 | 6.37 | 6.51 | 6.35 | 0.10 | 0.73 | 0.88 | 0.20 |

[1] Standard error of the mean (n = 17 or 18).

[2] Program × roughage level interactions.

[3] Program examines the comparison of Natural (NAT) vs. Conventional (CONV).

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

[5] Muscle color (1 = extremely dark red, 8 = extremely bright cherry red).

[6] Surface discoloration (1 = no discoloration, 7 = total discoloration).

[7] Overall appearance (1 = extremely undesirable, 8 = extremely undesirable).

**Table 4.3.** The effects of treatment on proximate analysis of LM

| | Production Program | | | Roughage Level | | | *P*-value | |
|---|---|---|---|---|---|---|---|---|
| Item | NAT | CONV | SE[1] | LOW | HIGH | SE[1] | Program[2] | Roughage Level[3] |
| n | 36 | 35 | - | 36 | 35 | - | - | - |
| Marbling score[4] | 512 | 446 | 12.28 | 485 | 473 | 12.28 | <0.01 | 0.50 |
| Moisture, % | 68.85 | 70.18 | 0.32 | 69.34 | 69.70 | 0.32 | <0.01 | 0.43 |
| Lipid, % | 6.22 | 4.63 | 0.31 | 5.70 | 5.14 | 0.27 | <0.01 | 0.10 |
| Protein, % | 23.29 | 24.25 | 0.20 | 23.68 | 23.86 | 0.20 | <0.01 | 0.54 |
| Ash, % | 1.12 | 1.19 | 0.03 | 1.16 | 1.15 | 0.03 | 0.04 | 0.61 |
| Cholesterol, mg/100 g | 68.67 | 70.19 | 2.80 | 66.85 | 72.01 | 2.80 | 0.70 | 0.19 |

[1] Standard error of the mean (n = 35 or 36).

[2] Program examines the comparison of Natural (NAT) vs. Conventional (CONV). No program x level interaction existed (P > 0.10).

[3] Roughage level examines the comparison of 7% (LOW) and 12% (HIGH) dietary DM roughage inclusion level. No program x level interaction existed (P > 0.10).

[4] 400 = Small00, 500 = Modest00, 600 = Moderate00.

**Table 4.4.** The effects of treatment on mineral concentration (mg/100g, As-Is Basis)

| | Production Program | | | Roughage Level | | | *P*-value | |
|---|---|---|---|---|---|---|---|---|
| Item | NAT | CONV | SE[1] | LOW | HIGH | SE[1] | Program[2] | Roughage Level[3] |
| n | 36 | 35 | - | 36 | 35 | - | - | - |
| Potassium | 334.72 | 342.34 | 3.76 | 340.00 | 337.06 | 3.76 | 0.15 | 0.58 |
| Sodium | 46.76 | 48.56 | 0.64 | 47.74 | 47.59 | 0.64 | 0.05 | 0.86 |
| Phosphorous | 193.76 | 202.00 | 2.46 | 198.14 | 197.61 | 2.46 | 0.02 | 0.88 |
| Zinc | 3.51 | 3.44 | 0.07 | 3.44 | 3.51 | 0.07 | 0.40 | 0.42 |
| Magnesium | 20.85 | 22.58 | 0.29 | 21.51 | 21.91 | 0.29 | <0.01 | 0.32 |
| Iron | 1.43 | 1.32 | 0.03 | 1.40 | 1.35 | 0.03 | <0.01 | 0.23 |
| Calcium | 5.65 | 5.22 | 0.16 | 5.45 | 5.43 | 0.16 | 0.06 | 0.95 |
| Copper | 0.059 | 0.053 | <0.001 | 0.057 | 0.056 | <0.001 | <0.01 | 0.33 |
| Manganese | 0.008 | 0.008 | <0.001 | 0.008 | 0.008 | <0.001 | 0.20 | 0.63 |

[1] Standard error of the mean (n = 35 or 36).

[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. No program x level interaction existed (P > 0.10).

**Table 4.5.** The effects of treatment fatty acid composition of LM

| | Production Program | | | Roughage Level | | | *P*-value | |
|---|---|---|---|---|---|---|---|---|
| Item | NAT | CONV | SE[2] | LOW | HIGH | SE[2] | Program[3] | Roughage Level[4] |
| Fatty Acid[1], % | | | | | | | | |
| 14:0 | 2.68 | 2.53 | 0.07 | 2.55 | 2.65 | 0.07 | 0.15 | 0.43 |
| 14:1 | 0.53 | 0.48 | 0.03 | 0.49 | 0.51 | 0.03 | 0.20 | 0.56 |
| 15:0 | 0.34 | 0.32 | 0.01 | 0.35 | 0.30 | 0.01 | 0.07 | <0.01 |
| 16:0 | 27.20 | 26.04 | 0.26 | 26.30 | 26.95 | 0.26 | <0.01 | 0.07 |
| 16:1 | 3.07 | 2.83 | 0.07 | 2.91 | 3.00 | 0.07 | 0.03 | 0.40 |
| 17:0 | 1.06 | 1.01 | 0.03 | 1.14 | 0.93 | 0.03 | 0.09 | <0.01 |
| 17:1 | 0.70 | 0.66 | 0.03 | 0.75 | 0.61 | 0.03 | 0.10 | <0.01 |
| 18:0 | 15.29 | 17.05 | 0.30 | 16.01 | 16.34 | 0.30 | <0.01 | 0.42 |
| 18:1 c12 | 0.24 | 0.17 | 0.01 | 0.21 | 0.20 | 0.01 | <0.01 | 0.34 |
| 18:1 c9 | 38.76 | 37.60 | 0.31 | 38.70 | 37.65 | 0.31 | 0.01 | 0.02 |
| 18:1 t11, t10 | 2.28 | 2.78 | 0.08 | 2.48 | 2.57 | 0.08 | <0.01 | 0.40 |
| 18:2, n-6 | 3.05 | 3.80 | 0.19 | 3.38 | 3.47 | 0.19 | <0.01 | 0.58 |
| 18:3, n-3 | 0.40 | 0.38 | 0.01 | 0.39 | 0.40 | 0.01 | 0.35 | 0.50 |
| 20:2, n-6 | 0.08 | 0.05 | 0.01 | 0.05 | 0.07 | 0.01 | 0.02 | 0.20 |
| 20:3, n-6 | 0.19 | 0.17 | 0.01 | 0.17 | 0.19 | 0.01 | 0.13 | 0.11 |
| 20:4, n-6 | 0.06 | 0.04 | 0.01 | 0.05 | 0.04 | 0.01 | <0.01 | 0.45 |
| 20:5, n-3 | 0.08 | 0.09 | 0.01 | 0.08 | 0.09 | 0.01 | 0.37 | 0.05 |
| 22:4, n-6 | 0.06 | 0.04 | 0.01 | 0.05 | 0.04 | 0.01 | <0.01 | 0.45 |
| 22:5, n-3 | 0.21 | 0.25 | 0.01 | 0.22 | 0.24 | 0.01 | 0.03 | 0.17 |
| Sum, % | | | | | | | | |
| SFA | 46.73 | 47.09 | 0.34 | 46.51 | 47.32 | 0.33 | 0.46 | 0.10 |
| MUFA | 46.70 | 45.55 | 0.33 | 46.67 | 45.58 | 0.33 | 0.01 | 0.02 |
| PUFA | 4.31 | 4.98 | 0.20 | 4.58 | 4.72 | 0.20 | <0.01 | 0.45 |
| PUFA, n-3 | 0.69 | 0.72 | 0.02 | 0.68 | 0.73 | 0.02 | 0.29 | 0.09 |
| PUFA, n-6 | 3.43 | 4.11 | 0.20 | 3.74 | 3.80 | 0.20 | <0.01 | 0.72 |
| Ratio | | | | | | | | |
| PUFA:SFA | 0.09 | 0.11 | 0.01 | 0.10 | 0.10 | 0.01 | <0.01 | 0.81 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| MUFA:SFA | 1.00 | 0.97 | 0.01 | 1.01 | 0.97 | 0.01 | 0.09 | 0.04 |
| USFA:SFA | 1.10 | 1.08 | 0.01 | 1.11 | 1.07 | 0.01 | 0.34 | 0.06 |
| n-6:n-3 | 5.70 | 6.01 | 0.47 | 5.88 | 5.82 | 0.47 | 0.39 | 0.86 |
| Atherogenic Index | 0.75 | 0.72 | 0.01 | 0.72 | 0.75 | 0.01 | 0.14 | 0.09 |

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[1] Individual fatty acids were calculated as a percentage of total fatty acids in the total lipid extracted from muscle tissue.

[2] Standard error of the mean (n = 35 or 36).

[3] Program examines the comparison of Natural (NAT) vs. Conventional (CONV). No program x level interaction existed (P > 0.10).

[4] Roughage level examines the comparison of 7% (LOW) and 12% (HIGH) dietary DM roughage inclusion level. No program x level interaction existed (P > 0.10).

# CHAPTER V

## EFFECTS OF TECHNOLOGY USE IN FEEDLOT PRODUCTION SYSTEMS ON FEEDLOT PERFORMANCE AND CARCASS CHARACTERISTICS – YEAR II

**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 one of three treatments in a RCBD (14 steers/pen; 8 pens/treatment). Treatments consisted of an all-natural treatment (**NAT)**, a conventional treatment (**CONV**), and a conventional treatment with the addition of a beta-agonist (**CONV-Z**). The NAT cattle received no growth promoting technologies. The CONV and CONV-Z cattle were implanted with 40 mg of estradiol and 200 mg of trenbolone acetate 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 at 6.76 mg/kg (90% DM basis) for the last 20 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; $P < 0.01$) a 32.6% improvement in carcass efficiency (0.126 vs 0.095; $P < 0.01$), and a 21.8% improvement (1.34 vs. 1.10 Mcal/kg; $P < 0.01$) in calculated dietary $NE_g$ 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; $P < 0.01$). Fat thickness was greater for CONV cattle compared to CONV-Z cattle (1.22 vs 1.10 cm; $P = 0.03$). Ribeye area was increased by 3.6 cm$^2$ for CONV-Z steers compared to CONV steers (92.29 vs 88.67 cm$^2$; $P = 0.02$) and 12.1 cm$^2$ for CONV-Z steers compared to NAT steers (92.29 vs. 80.16 cm$^2$; $P < 0.01$), resulting in a 9.6 percentage unit increase in USDA Yield Grade (YG) 1 (15.14 vs. 5.52%; $P < 0.05$) and a 21.6 percentage unit reduction in USDA YG 3 for CONV-Z steers compared to CONV steers (30.70 vs. 52.32%; $P < 0.05$). There was no difference in marbling score for CONV steers compared to NAT steers (470 vs. 471; $P = 0.99$); however, CONV-Z steers had a lower marbling score compared to the other treatments (432; $P < 0.01$), resulting in an 11.7 percentage 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 Yield Grade compared to NAT.

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

## INTODUCTION

Efficiency enhancing technologies have been used in beef production in the United States since diethystilbesterol was approved in the 1950s (Raun and Preston, 2002). Zeranol implants were first used in cattle in 1969, and in the 1980s and 1990s the use of estradiol/trenbolone acetate combination implants became popular. Most recently, nutritionists and feedlot management have adopted the use of two β-adrenergic agonists (**BAA**; ractopamine hydrochloride; 2003; and zilpaterol hydrochloride; 2006 and Johnson et al., 2013). Capper (2011) compared resource use and beef production from 2007 to 1977 and found that beef production in 2007 requires only 69.9% of animals and 67% of land to produce 1 billion kg of beef compared to 1977, as well as an increase in average beef yield per animal from 274 kg to 351 kg. These drastic improvements in production efficiency partially stems from the development and adoption of new technologies. According to USDA (2014), beef slaughter production in 1950 was 4.3 billion kg of beef, and in 2012 it was estimated at 11.7 billion kg.

Extensive research has been conducted examining the effects of growth implants, BAA and other technologies such as ionophores on feedlot performance and carcass characteristics, however, few studies have examined these technologies in a systems approach. Most recently, Maxwell et al. (2014) examined the effects of beef production systems examining the effects of an all-natural system (without use of growth implants, beta-agonists, and ionophores) compared to a conventional system with the use of a BAA with differing roughage levels, beginning at the stocker phase. The objectives of this study were to examine the effects of 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 an 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, respectively. 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 from South Dakota and Nebraska, respectively.

The morning after arrival, each group was weighed individually identified with a visual numbered tag as well as an electronic identification (EID). This BW was used to sort the cattle into approximate weight groups. On May 01 and May 03, 2013, the cattle from South Dakota and Nebraska were processed and sorted into approximate weight blocks, respectively. All steers were vaccinated against clostridial toxins (Vision 7, Merck Animal Health, DeSoto, KS), IBR, PI3, BRSV, and BVD type I and II, *Mannheimia haemolytica* and *Pasteurella multocida* (Vista Once, Merck Animal Health), 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 was 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 07, 09, 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 and stratified by initial temperament, exit and hide scores and exit speed 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 beta-agonist at the end of the feeding period (**CONV-Z**). The NAT cattle received no antibiotics, growth implants, or beta-agonists, and, if antibiotic treatment was deemed necessary, removed from the trial. These cattle were eligible for and received the Creekstone Farms Natural Black Angus Beef premium at slaughter. The CONV and CONV-Z cattle were implanted with 40 mg of estradiol and 200 mg of trenbolone acetate (Revalor-XS, Merck Animal Health) on d 0. They were also fed 33 and 9 mg/kg of monensin and tylosin (Rumensin and Tylan, Elanco Animal Health, Greenfield, IN) daily, respectively. The CONV and CONV-Z cattle were eligible for antibiotic treatment if deemed as necessary. The CONV-Z cattle were fed zilpaterol hydrochloride (Zilmax, Merck Animal Health) at 6.76 mg/kg (90% DM basis) for the last 20 d on feed, and zilpaterol was withdrawn from feed for 3-5 d prior to slaughter. All cattle were fed the same base 93% concentrate diet (Table 5.1). Cattle were housed in 24, 12.2 x 30.5 m soil-surfaced feedlot pens with 12.2 m fence-line concrete feed bunk 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 upon projected slaughter BW and a visual appraise of 12th rib-fat thickness. 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 Zilmax. The light 2 blocks were weighed and the CONV-Z started on Zilmax on October 08, 2013 (d 138). This date is referenced as d 0Z. The cattle were then weighed on d 10Z and d 20Z. Cattle on CONV-Z were fed Zilmax at a calculated rate of 87.6 $mg \cdot steer^{-1} \cdot d^{-1}$ based upon calculated intake and assayed zilpaterol values with a 3-5 d period of Zilmax withdrawal. A 4% pencil shrink was applied to all BW for calculation of performance. Performance was calculated on a deads and removals included basis, as body weights were obtained at time of death or removal from each animal.

Cattle were fed for an average of 136 days. 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 ship date was due to the requirements of the packing facility in that they only slaughter NAT cattle on Fridays of each week. All cattle were weighed prior to 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. 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; Oranienbury, Germany). Liver scores were obtained by the methods as in Maxwell et al. (2014).

### *Feed and Bunk Management*

Cattle were adapted to assigned finishing diets during an 18 d adaption period. During this phase, CONV calves were fed a portion of a base receiving ration with Rumensin and Tylan and their treatment diet, and the NAT calves were fed the same receiving diet without Rumensin or Tylan and their treatment diet. This was accomplished using a two-ration blend method. Each day, treatment diet was increased by 5.6% DM and receiving diet was decreased by 5.6% DM until calves were adapted to the finishing diet. Following adaptation, calves were fed twice daily at 0700 h and 1300h. 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 insure no cross contamination of treatment diets. Feed bunks were managed to contain trace amounts of feed, and bunks were cleaned prior to 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 insure no cross contamination occurred. Zilpaterol 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 Zilmax per treatment designation. A 76 L concrete water tank (Model J 360-F, Johnson Concrete, Hastings, NE) was shared between two pens and was cleaned three times weekly throughout the 135 d experiment. All steers were fed a direct-fed microbial (Bovamine, Nutrition Physiology Company, Guymon, OK) at 1 g $\cdot$steer$^{-1}\cdot$d$^{-1}$. Direct-fed microbial delivery was accomplished by mixing the Bovamine dose with 2.26 kg ground corn in a Kitchen-Aid mixer for 5 minutes 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 AM feeding.

All diets were formulated to meet or exceed NRC (2000) requirements. For all diets, minerals, vitamins and feed additives were contained in a ground corn and wheat-midd based pelleted supplemented mixed at the Oklahoma State University Feed Mill.

Rations samples were collected once/week, dried in a forced air oven for 48 h at 60° C to determine dry matter. An average dry-matter was calculated for the feeding period and actual DMI consumption was calculated at the end of the study by dividing total pounds 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 zilpaterol hydrochloride (Merck Pharmaceutical Laboratory; Lawrence, KS). Orts were obtained on each weigh-day and during inclement weather events. A 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).

### ***Statistical Analysis***

All animal performance data were analyzed as a RCBD using PROC MIXED (SAS 9.3; SAS Inst. 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 experimental unit and weight block included as a random effect. The USDA Quality Grade, Yield Grade, and liver scores were analyzed using PROC GLIMMIX (SAS 9.3; SAS Inst. Cary, NC). 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 prior to feeding zilpaterol, while 1 died during zilpaterol feeding (d 11Z). Two steers were removed from the trial for being lame (1-CONV and 1-NAT). The lame NAT steer was treated by washing out the lame limb and flushing with iodine for 5 d. No significant improvement was noted so the animal was treated with an antibiotic and removed from the trial. The CONV steer that was lame was administered an antibiotic along with washing and flushing with iodine. Again, no significant improvement was noted so the animal was pulled off-trial. 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.

### *Feedlot Diet Analyses*

Tables 5.1 and 5.2 show the actual diet DM formulation and analyzed nutrient composition throughout the study. These diets 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 zilpaterol for the last 20 DOF for CONV-Z.

Feed samples were collected for monensin and zilpaterol 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 $mg \cdot steer^{-1} \cdot d^{-1}$ monensin, lower than the manufacturer recommended dose of 360 $mg \cdot steer^{-1} \cdot d^{-1}$ monensin.

Zilpaterol hydrochloride was assayed from the composited weekly samples collected uring the period which zilpaterol 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 upon actual DMI intake during the zilpaterol period, zilpaterol intake was 87.6 mg·steer$^{-1}$·d$^{-1}$, within the labeled dose of 60 to 90 mg·steer$^{-1}$·d$^{-1}$.

### *Feedlot Performance – Live Basis*

Body weights collected throughout the experiment are shown in Table 5.3. 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 20 Z 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 ($P \geq 0.16$). However, CONV-Z steers had an 8 kg numerically heavier BW at d 20 Z (600 vs. 592 kg; $P = 0.19$). Interim and overall feedlot performance is shown in Table 5.4. Throughout the experiment, there was no effect of treatment on DMI ($P \geq 0.26$), except for when Zilmax was fed (d0Z-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; $P \leq 0.04$). Though not significantly different, there was a 0.42 kg/d reduction in DMI for CONV-Z steers compared to CONV steers (10.58 vs. 11.00 kg; $P = 0.41$) during the period in which zilpaterol was fed. 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-d20Z. Feed efficiency was not different between CONV and NAT steers during the last 20 days 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 did improve calculated $NE_m$ and $NE_g$ of the diets fed (Table 5.7). 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 mcal/kg; $P \leq 0.05$), with the same being true for diet $NE_g$ (1.34 vs. 1.29 vs. 1.10 mcal/kg; $P \leq 0.05$). During the last 20 days on feed, the calculated $NE_m$ and $NE_g$ of the diet was 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 5.5 shows feedlot performance calculated on a carcass basis. On a carcass adjusted basis, ADG and G:F was 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 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 zilpaterol period.

### ***Carcass Characteristics***

Table 5.6 shows the effects of treatment on carcass characteristics. Dressing percentage was greatest for CONV-Z steers (64.68 vs. 63.23% $P < 0.01$), 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 12th rib-fat thickness (**FT**) compared to CONV-Z cattle (1.22 vs. 1.20 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 dorsi* was increased by 3.6 $cm^2$ for CONV-Z steers compared to CONV steers (92.29 vs 88.67 $cm^2$; $P = 0.02$) and 12.1 $cm^2$ compared to NAT (92.29 vs. 80.16 $cm^2$; $P < 0.01$). Due to the decrease in FT and increase in *Longissimus dorsi*, USDA Yield Grade was lowest for CONV-Z steers (2.65 vs. 3.02; $P < 0.01$) 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. 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 percentage 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 percentage unit increase in USDA Yield Grade 1 carcasses (15.14 vs. 5.52%; $P < 0.05$) and a 21.6 percentage unit decrease in USDA Yield Grade 3 carcasses (30.70 vs. 52.32%; $P < 0.05$) for CONV-Z steers compared to CONV steers. There was no difference in USDA Yield Grade 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 very similar to those reported by Maxwell et al. (2014). Overall feedlot performance was poorer in the current experiment compared to Maxwell et al. (2014), most likely due to the facilities in which the cattle were fed. The cattle in the current experiment were fed in outside unshaded pens, whereas the cattle mentioned in Maxwell et al. (2014) were fed in partially shaded pens. Published data show feedlot performance is improved during summer months when shade is provided (Mitlohner et al., 2002; Sullivan et al., 2011). Furthermore, the cattle in the current experiment were weighed every 28 d, much more frequently than in Maxwell et al. (2014) which could negatively affect performance. Similarly to Maxwell et al. (2014), conventionally fed cattle had a slightly greater DMI compared to NAT cattle. In the current experiment, there was a 2.9% numerical increase in DMI for conventionally fed cattle compared to NAT. In contrast, Cooprider et al. (2011) noted no difference in DMI for steers receiving technologies to those fed naturally. It is interesting to note that the CONV and CONV-Z cattle consumed more feed for the last 20 days on feed than the naturals. Perhaps this is due to the large difference in BW at the end of the feeding period. Also, it has been shown that implanted cattle will consume more feed than non-implanted cattle (Mader et al., 1994; Sawyer et al., 2003; Wileman et al. 2009). However, Parr et al. (2011) noted that DMI was not increased until after d 56 for implanted cattle compared to non-implanted when using the same implant as the one used in this study. Although not significantly different, there was a 4% reduction in DMI for CONV-Z cattle compared to CONV during the period in which zilpaterol was fed. This decrease in DMI is similar to the results reported by Holland et al. (2010) where a 4.4% decrease in DMI was noted when cattle were fed zilpaterol. Montgomery et al. (2009) noted a trend for a 1.9% decrease in feed intake when zilpaterol was fed in beef steers. Moreover, Rathmann et al. (2012) showed a 2% reduction in feed intake during the 20 days in which zilpaterol was fed. However, other studies have shown no effect of zilpaterol on feed intake (Elam et al., 2009 and Parr et al., 2011). McEvers et al. (2014) reported a 2.8% decrease in feed intake for the 20 d zilpaterol period. Typically this decrease in DMI during the period in which zilpaterol is fed does not affect overall DMI for the length of the feeding period. The magnitude in improvement of ADG and efficiency for CONV-Z compared to NAT was greater in the current study than compared to 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). This could potentially be due to the differences in genetic makeup of the cattle. The cattle in the current experienced consisted of a much greater proportion of Continental type cattle, whereas cattle in previous experiment were primarily English based. These results are similar to those reported by Cooprider et al. (2011) where a 33.3% improvement in feed efficiency was noted when feeding 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 days (Cooprider 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.

The improvement in performance during the 20 d of zilpaterol 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 efficiency when zilpaterol was fed compared to cattle not fed zilpaterol for 20 days, similar to the 42.8 and 45.6% improvements 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 efficiency for zilpaterol compared to no-zilpaterol. This drastic improvement in ADG and efficiency translates to a significant improvement over the entire feeding period. Holland et al. (2010) reported a 3.1% improvement in efficiency for cattle fed zilpaterol compared to non-fed controls, whereas McEvers et al. (2014) reported a 4.0% improvement, slightly less than the 5.3% improvement in efficiency noted in this experiment. Zilpaterol use increases improvement in ADG and G:F by 3-5% over the large increase due to implants and ionophores. This is further confirmed by data published by Baxa et al. (2010) and Parr et al. (2011) which noted no interactions between implants and beta agonists, suggesting the improvement in performance is additive. 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%.

As has been previously established in the literature, zilpaterol is most effective on carcass weight gain, as typically the improvement in HCW exceeds that 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. This is difficult because of the inability to measure carcass weight on feeder cattle. Therefore initial carcass weight must be estimated. However, the calculated carcass performance reported here are similar to those reported by Parr et al. (2012), Rathmann et al. (2012), and Maxwell et al. (2014). Interestingly, the effects of treatment on carcass performance was similar to that observed for live performance. 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 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. Streeter et al. (2012) reported that the ratio of carcass gain to live gain to be 86% for steers. 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 30-40% 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 zilpaterol 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 prior to 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 4-6 days from when the d 20Z BW was taken and cattle were harvested. The CONV-Z cattle had a 1.64 percentage unit improvement in dressing percentage compared to NAT cattle and 1.25 percentage unit improvement compared to CONV cattle. Compared to NAT steers, this improvement in dressing percentage is very similar to the 1.58 percentage 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 percentage unit improvement reported by Holland et al. (2010) and Montgomery et al. (2009) respectively. However, it is less than the 1.7 percentage unit increase noted by McEvers et al. (2014). Due to the slightly smaller improvement in dress for CONV-Z steers compared to CONV steers, the difference in HCW was less than the 15 kg advantage typically expected when feeding zilpaterol (Elam et al., 2009). This is due to differences in BW between the CONV steers and CONV-Z steers treatments prior to feeding zilpaterol. The cattle in this experiment were sorted to treatments at the initiation of the study, and in the lightest block of cattle d 0Z BW was significantly greater for CONV cattle compared to CONV-Z cattle. Nonetheless, there was a 10.2 kg improvement in calculated carcass gain during the period in which zilpaterol was fed. As expected from 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 zilpaterol on FT has been quite variable. Avendaño-Reyes et al. (2006), Rathmann et al. (2012) and McEvers et al. (2014) have reported decreases in FT when feeding zilpaterol 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., 2012). The cattle in this experiment were considerably trimmer than the cattle reported by Maxwell et al. (2014), which were slaughtered with approximately 1.77 cm 12th rib-fat thickness. However, in each experiment, FT was similar for NAT and CONV-Z cattle fed the same number of day. This indicates that cattle fed for an all-natural program will reach finish with similar 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 percentage 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), compared to NAT, there were no negative effects on USDA Quality Grade when cattle were implanted with a combination implant (CONV) as both treatments had 90% of the cattle grade USDA Choice or greater. Similarly, USDA Yield Grade distribution was not affected for CONV compared to NAT. However similar to Maxwell et al. (2014), there was a shift in USDA Yield Grade towards a Yield Grade 1 for CONV-Z compared to NAT.

Similar to Cooprider 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) that noted a significant increase in abscessed livers for naturally fed cattle compared to conventionally fed cattle, due to inclusion of tylosin in conventional diets. Overall occurrence of liver abscesses regardless of treatment was significantly less than reported by Maxwell et al. (2014) in the current study. However, the animals noted as having liver abscesses falls within the expected range discussed by Nagaraja and Chengappa (1998) of 12-32%.

## CONCLUSIONS

Capper (2012) determined that 22.4% more land, 17.8% more water and 1,211 x $10^3$ more animals would be required to produce 1.0 x $10^9$ kg of beef for cattle raised in a NAT system compared to a CONV system, resulting in a 17.4% increase in carbon footprint. Stackhouse et al. (2012) suggested that ionophores and implants reduce the carbon footprint by 7%, and beta agonists reduce it by 9%, for a total reduction of 16% in beef production. These improvements in environmental impact all stem from the improvements in animal performance and production. The advantages of producing beef in a conventional manner compared to a natural system are clear. 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 feed requirements by 2050, it will be imperative that efficiency enhancing technologies continue to be used in beef production.

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**Table 5.1.** Ingredient composition (% DM basis) of diets fed[1]

| | Experimental diet[2] | | |
|---|---|---|---|
| Ingredient | NAT | CONV | CONV-Z[5] |
| 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® | 15.15 | 15.15 | 15.15 |
| Liquid supplement | 10.37 | 10.37 | 10.37 |
| Dry supplement, B-272[3] | 5.14 | - | - |
| Dry supplement, B-273[4] | - | 5.17 | 5.17 |

[1] Actual DM formulation calculated based upon As-Is formulations and weekly ingredient DM values.

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

[3] 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.

[4] 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.

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

**Table 5.2.** 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 |

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

[2] All 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.

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

**Table 5.3.** The effects of treatment on body weights, deads and removals included[1]

| | Treatment[2] | | | | |
|---|---|---|---|---|---|
| Item | NAT | CONV | CONV-Z | SE[3] | *P*-value[3] |
| 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 0 Z | 522$^{a}$ | 567$^{b}$ | 565$^{b}$ | 6.35 | <0.01 |
| d 10 Z | 529$^{a}$ | 581$^{b}$ | 583$^{b}$ | 5.76 | <0.01 |
| d 20 Z | 540$^{a}$ | 592$^{b}$ | 600$^{b}$ | 6.60 | <0.01 |
| Carc. adj. final BW[5], kg | 544$^{a}$ | 603$^{b}$ | 617$^{c}$ | 7.58 | <0.01 |
| Hot carcass weight, kg | 348$^{a}$ | 386$^{b}$ | 394$^{c}$ | 5.07 | <0.01 |

[a,b,c] Means without a common superscript differ ($P < 0.05$).

[1] Data were analyzed with deads (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 a HCW at time of removal.

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

[3] Standard error of the mean (n = 8). *P*-value is for overall ANOVA.

[4] A pencil shrink of 4% was applied.

[5] Carcass adjusted performance data was calculated based upon an average dressing percentage of 63.80%.

**Table 5.4.** The effects of treatment on live feedlot performance, deads and removals included[1]

| | Treatment[2] | | | | |
|---|---|---|---|---|---|
| Item | NAT | CONV | CONV-Z | SE[3] | *P*-value[3] |
| Pens | 8 | 8 | 8 | - | - |
| Total head | 112 | 112 | 112 | - | - |
| Days on feed | 136 | 136 | 136 | - | - |
| 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,b,c] Means without a common superscript differ ($P < 0.05$).

[1] Data were analyzed with deads (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 a HCW at time of removal.

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

[3] Standard error of the mean (n = 8). *P*-value is for overall ANOVA.

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

**Table 5.5.** The effects of treatment on carcass feedlot performance, deads and removals included[1]

| 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 | - | - |
| Carcass adjusted[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. 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. dress, % | 58.10 | 58.10 | 58.09 | 0.24 | 0.54 |
| Pred. 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,b,c] Means without a common superscript differ ($P < 0.05$).

[1] Data were analyzed with deads (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 a HCW at time of removal.

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

[3] Standard error of the mean (n = 8). *P*-value is for overall ANOVA.

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

[5] Predicted HCW is calculated as d 0Z BW x 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.

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

**Table 5.6.** 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 | | | | | |
| 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 | | | | | |
| 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,b,c] Means without a common superscript differ ($P < 0.05$).

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

[2] Standard error of the mean (n = 8). *P*-value is for overall ANOVA.

[3] 400 = Small00, 500 = Modest00, 600 = Moderate00.

**Table 5.7.** The effects of treatment on dietary energy calculations[1]

| | Treatment[2] | | | | |
|---|---|---|---|---|---|
| Item | NAT | CONV | CONV-Z | SE[3] | *P*-value[3] |
| Pens | 8 | 8 | 8 | - | - |
| Total head | 112 | 112 | 112 | - | - |
| Days on feed | 136 | 136 | 136 | - | - |
| | | | | | |
| 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,b,c] Means without a common superscript differ ($P < 0.05$).

[1] Data were analyzed with deads (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 a HCW at time of removal. Calculated according to Zinn et al., 1992.

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

[3] Standard error of the mean (n = 8). *P*-value is for overall ANOVA.

# CHAPTER VI

## EFFECTS OF TECHNOLOGY USE IN FEEDLOT PRODUCTION SYSTEMS ON FEEDLOT PERFORMANCE, CARCASS CHARACTERISTICS AND FEEDING BEHAVIORS OF CROSSBRED BEEF STEERS

**ABSTRACT:** The objectives of this study were to examine the effects of a technology enhanced system compared to an all-natural production program on feedlot performance, feeding behaviors and carcass characteristics. Crossbred beef steers (n = 54; initial BW = 391 ± 2.6 kg) were randomized to one of two treatments in a RCBD (13-14 steers/pen; 27 steers/treatment). Treatments consisted of an all-natural treatment (NAT) and a conventional treatment (CONV-Z). The NAT cattle received no growth promoting technologies. The CONV-Z cattle were implanted with 40 mg of estradiol and 200 mg of trenbolone acetate on d 0 and were fed 33 and 9 mg/kg of monensin and tylosin daily, respectively as well as zilpaterol hydrochloride at 6.76 mg/kg (90% DM basis) for the last 20 DOF. Gain was improved by 45.1% (1.77 vs. 1.22 kg/d; $P < 0.01$) and feed efficiency by 45.5% (0.163 vs. 0.112; $P < 0.012$) for CONV-Z steers compared to NAT steers. Daily water intake was numerically greater for NAT steers compared to CONV-Z steers consistently throughout the study (56.26 vs. 53.59 L/d; $P = 0.43$). Thus, total efficiency was improved by 50% CONV-Z steers compared to NAT steers (0.027 vs. 0.018; $P < 0.01$). Overall dietary $NE_g$ was improved by 30.1% for CONV-Z steers compared to NAT steers (1.34 vs. 1.03

mcal/kg; $P < 0.01$). The NAT steers consumed more (8.22 vs 7.59 meals/d; $P = 0.03$) smaller feed meals (1.34 vs 1.46 kg/meal; $P = 0.02$), resulting in more time spent at the feed bunk (85.36 vs 73.19 min/d; $P < 0.01$) throughout the day compared to CONV-Z steers. There was no effect on the number of water meals/d (7.20 vs 6.86 meals/d; $P = 0.35$), however water meal length was greater for NAT steers compared to CONV-Z steers (3.23 vs 2.58 min/meal; $P < 0.01$), resulting in more time spent at the water trough throughout the day (23.71 vs. 17.80 min/d; $P < 0.01$). Dressing percentage was increased by 2.17 percentage units (65.31 vs. 63.14; $P < 0.01$) for CONV-Z steers compared to NAT steers, resulting in a 48 kg heavier carcass (388 vs. 340, kg; $P < 0.01$). *Longissimus* area was increased by 11.09 $\text{cm}^2$ (87.25 vs. 76.15, $\text{cm}^2$; $P < 0.01$) for CONV-Z steers compared to NAT steers, and marbling score was greater for NAT steers compared to CONV-Z steers (504 vs. 410; $P < 0.01$). The results of this experiment show that CONV-Z production improves feedlot performance and carcass cutability compared to NAT with differences in feed and water intake behavior. Moreover these data suggest that the use of technologies may improve water use efficiency, resulting in a large improvement in total feed and water resource use efficiency.

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

## INTRODUCTION

Technology use in beef cattle has shown a clear improvement in feedlot performance and carcass cutability. Maxwell et al. (2014a) and (2014b) examined the effects of a conventional production system with the use of implants, ionophores and beta-adrenergic agonists compared to a natural system using no technologies, with results confirming this. These studies focused on the improvement in animal performance, and differences in carcass characteristics in a pen setting.

Little is known about the effects of efficiency enhancing technologies on feed-intake variation and water consumption in feedlot steers. Schwartzkopf-Genswein et al. (2011) examined the relationship between feeding behavior and performance of beef steers using a Grow-Safe system, and found that the best performing animals had the highest variation in intake. Nutritionists typically believe naturally fed cattle are more susceptible to digestive disturbances due to the absence of an ionophore in the diet (Cheng et al., 1998). Most data pertaining to determining water intake in feedlot cattle have been centered around environmental stressors and its role on water intake (Mader and Davis, 2004; Arias and Mader, 2011; Sexson et al., 2012). Data from these studies indicate that weather variables such as ambient temperature and temperature humidity index play a large role in water consumption of feedlot cattle, but little data exists examining the effects of technology use on water intake. Capper (2012) determined a 17.9% increase in water use/1.0 x $10^9$ kg of beef production when cattle are finished in a natural system compared to a conventional system. However most of this improvement in water use is due to the increased growth rate when expressed/unit of beef production. The objective of this experiment was to determine the effects of technology use in a conventional and natural production system on feedlot performance, feed intake variation, water consumption, total resource-use efficiency and carcass characteristics.

## MATERIALS AND METHODS

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

### *Cattle Management*

Eighty-seven steers were sorted from the pen-level study by Maxwell et al. (2014a) and used for this experiment. Of the 87 steers, 64 were chosen to be trained for individual feed and intake monitoring using the Insentec monitoring system (Insentec, Marknesse, the Netherlands).

This system allows for quantification of feed and water intake on an individual animal basis. The system captures the date and time of entrance and exit, as well as by subtraction the amount of feed or water consumed at each visit, continuously. These data are then communicated to a base computer for storage and summary. These animals were processed via the same protocol as Maxwell et al. (2014a). The steers began training on May 04, 2013, and the study was initiated on May 21, 2013. During training, 7 steers were removed due to the inability to learn the system. Therefore, 54 steers (28 – South Dakota and 26 –Nebraska) were used for the study. Steers were weighed, and chute temperament, exit speed and hide score were obtained on d -1. The cattle were blocked by source and stratified by initial temperament, exit and hide score and exit speed. On d 0, all cattle were weighed, and randomly sorted to study pens (2 blocks; 2 pens/treatment; 13-14 steers/pen; 27 steers/treatment; initial BW = 391 ± 2.57 kg). Treatments consisted of an all-natural treatment (NAT) and a conventional treatment (CONV-Z) as described by Maxwell et al. (2014a). Cattle were housed in 4, 11.9 x 30.5 m soil-surfaced feedlot pens with a 6.10 m covered awning. The pens each contained 6 feed stations and 1 water station. Each feed bin including the water bin was 1.00 m wide, 0.75 m high with a depth of 0.84 m. Water bins were programmed to continuously contain 35 L of water.

Cattle were weighed on d 28 and 56 of the finishing phase. At d 56, cattle were projected into slaughter groups based upon weight and finish with the cattle in Maxwell et al. (2014a). On August 20, 2013, all were weighed and the CONV-Z cattle were started on Zilmax. This date is referenced as d 0Z, the cattle were then weighed on d 10Z, and d 20Z. Cattle on CONV-Z were fed Zilmax at a calculated rate of 87.6 mg·steer$^{-1}$·d$^{-1}$ based upon calculated intake and assayed zilpaterol values with a 3 d withdrawal. A 4% pencil shrink was applied to all BW for calculation of performance.

Cattle were fed for 115 days. The cattle were slaughtered on September 12 and 13, 2013 at Creekstone Farms, Arkansas City, KS. Final BW, performance calculations, and carcass data collection was as described by Maxwell et al. (2014a). Chill time was the same as reported by Maxwell et al. (2014a).

### *Feed and Bunk Management*

Cattle were adapted to assigned finishing diets similar to Maxwell et al. (2014a). Following adaptation, calves were fed twice daily at 0700 h and 1300h. 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 and CONV-Z at each feeding. Within pen, all animals were programmed to be able to access any bin. Therefore, for each feeding, the called amount of feed was equally spread across all 6 feed bins within the pen. Flush batches were utilized at the end of each feeding to insure no cross contamination of treatment diets. Feed bunks were managed to contain trace amounts of feed, and bunks were cleaned prior to each feeding to remove manure, hair, etc. Zilpaterol 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) ration for CONV-Z and NAT was similar, with the exception of the difference in Rumensin, Tylan, and Zilmax/treatment designation. Water bins were cleaned three times weekly throughout the experiment.

At every weigh day, the feed and water bins were checked for weighing accuracy using a 22.7 kg certified weight. Bins were recalibrated if greater than 1% variation was found. Throughout the study, the feed system was closely monitored for functionality. Any time the system was not functioning properly a note was made for correction in the data analysis. For data summary, all feed and water visits were summed to meals throughout each day. To qualify as a meal, intake must have been greater than or equal to 0.0 kg. Every feeding event within a 5 min interval was summed into a meal. For the initiation of a new meal, 5 min had to elapse since the last feeding event. This definition of meal has been previously used by Sowell et al. (1998), Parsons et al. (2004) and Schwartzkopf-Genswein et al. (2011). This calculation was used for calculating feed meals and water meals. Meals were then summed for a day and then to the specific time periods for data analysis. Total efficiency was calculated on a live animal basis. Total efficiency was calculated as ADG divided by the sum of all resources used (feed, water, as well as the water associated with the feed intake).

### *Statistical Analysis*

All calculations are the same as those described by Maxwell et al. (2014b). All animal performance data were analyzed as a RCBD using PROC MIXED (SAS 9.3; SAS Inst. Cary, NC). Animal was considered the experimental unit, and source was included as a random effect. All carcass data were analyzed with animal as experimental unit, and source was included as a random effect. Means were separated using Tukey adjustment method when overall ANOVA was significant ($P \leq 0.05$). Differences were considered significantly different when $P < 0.05$ and a trend when $0.05 \geq P \leq 0.15$.

## RESULTS

Due to power outages in the feeding system, there were 6 days deleted for both feed and water intake. Due to issues with training the cattle to drink from the water system and functionality of the water system, water intake was not measured until after Jun 02, 2013. Also one other day was deleted from water intake due to non-functionality of the water bins. In instances, where the system recorded a visit longer than 30 min and intake was less than 0.5 kg, the visit length was reset to 10 min, and any visit length longer than 50 min was reset to 30 min. There were no animals removed from the study.

### *Feedlot Diet Analyses*

Tables 6.1 and 6.2 show the actual diet DM formulation and analyzed nutrient composition throughout the study, respectively. These diets were formulated to meet or exceed NRC requirements (NRC, 2000) and are further described by Maxwell et al. (2014a).

No monensin was detected in the NAT rations with a reported value < 0.9 mg/kg. Monensin concentration for CONV-Z diets were 24.73 mg/kg DM, less than the 33 mg/kg formulated however,  calculated monensin intake with the assayed value of 24.73 mg/kg was 297 mg·steer$^{-1}$·d$^{-1}$ monensin, very similar to the common industry dose of 300 mg·steer$^{-1}$·d$^{-1}$ monensin.

Zilpaterol hydrochloride was assayed from the composited weekly samples during the period which zilpaterol 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 upon actual DMI intake during the zilpaterol period, zilpaterol intake was 87.7 mg·steer$^{-1}$·d$^{-1}$, very similar to the labeled dose of 70 to 90 mg·steer$^{-1}$·d$^{-1}$. Zilpaterol intake for each CONV-Z animal ranged from 68.6 mg·steer$^{-1}$·d$^{-1}$ to 106.7 mg·steer$^{-1}$·d$^{-1}$.

### *Feedlot Performance – Live Basis*

Initial BW was not different between treatments (Table 6.3; 391 ± 0.77 kg; $P = 0.77$). The effects of treatment on feedlot performance is shown in Table 6.4.  There was no effect of treatment on DMI throughout the study (10.90 vs. 10.90 kg/d; $P = 0.97$).  Water intake was numerically higher for NAT steers compared to CONV-Z steers (56.26 vs. 53.59 L/d; $P = 0.43$). This was true for every interim period, and there was a trend for an increase in water intake for d 0-28 (53.03 vs. 48.51 L/d; $P = 0.14$) for NAT steers compared to CONV-Z steers.  The use of technology increased live ADG by 45.1% (1.77 vs. 1.22 kg/d; $P < 0.01$) and G:F by 45.6% (0.163 vs. 0.112; $P < 0.01$) compared to NAT steers.  This improvement in ADG resulted in a 62 kg heavier final BW (588 vs. 526 kg; $P < 0.01$) for CONV-Z steers compared to NAT steers. Total efficiency was improved by 50% for CONV-Z steers compared to NAT steers (0.027 vs. 0.018; $P < 0.01$).  Calculated dietary $NE_m$ and $NE_g$ were improved by 22.0% (Table 6.8; 2.00 vs. 1.64 mcal/kg; $P < 0.01$) and 30.1% (1.34 vs. 1.03 mcal/kg; $P < 0.01$), respectively, for CONV-Z steers compared to NAT steers.

### ***Feedlot Performance – Carcass Basis***

On a carcass adjusted basis, ADG increased by 53.6% (Table 6.7; 1.92 vs. 1.25 kg/d; $P < 0.01$) and G:F improved by 53.9% (0.177 vs. 0.115; $P < 0.01$) resulting in a 76 kg heavier final carcass-adjusted BW (605 vs. 529 kg; $P < 0.01$) for CONV-Z steers compared to NAT steers. On an estimated carcass gain perspective, carcass ADG was improved by 42.2% (1.18 vs. 0.83 kg/d; $P < 0.01$), and efficiency was improved by 43.4% (0.109 vs. 0.076; $P < 0.01$) for CONV-Z steers compared to NAT steers. This drastic improvement in estimated carcass gain and efficiency is mostly due to the 100% improvement in carcass ADG (1.88 vs. 0.94 kg/d; $P < 0.01$) and 97.7% improvement in efficiency (0.178 vs. 0.090; $P < 0.01$) that occurred during the 20 d that zilpaterol was fed for CONV-Z steers. Based upon a predicted HCW prior to feeding zilpaterol and actual HCW, total HCW gain was 21.65 kg greater (43.21 vs. 21.56 kg; $P < 0.01$) for CONV-Z steers compared to NAT steers during the zilpaterol period.

### ***Feeding Behaviors – Feed Intake***

As previously mentioned, feed and water intake behaviors were recorded throughout the experiment. The variables measured were number of meals/d, meal size (kg/meal), meal length (min/meal) and total amount of time spent at the feed or water bin/d (min/d). As previously mentioned DMI intake was not different between CONV-Z and NAT steers, at any time-point throughout the study. However, NAT steers consumed more feed meals/d (Table 6.5; 8.22 vs. 7.59; $P = 0.03$) compared to CONV-Z steers. Meal size was smaller for CONV-Z steers (1.34 vs. 1.46 kg/meal; $P = 0.02$) compared to NAT steers. Moreover, there was a numerical increase in meal length for NAT steers (10.50 vs. 9.82 min/meal; $P = 0.18$), that resulted in more total min spent at the feeder/d (85.36 vs. 73.19; $P <0.01$) compared to CONV-Z steers. Interestingly, for the 3 time periods prior to the period in which zilpaterol was fed (d 0-28, d 28-56, and d 56-0Z), the above mentioned was true. However, during d 0Z-20Z, there was no difference in number of feed meals (7.49 vs. 7.47; $P = 0.95$), or size (1.45 vs. 1.42 kg/meal; $P = 0.69$) for CONV-Z steers compared to NAT steers. Interestingly, meal length was significantly greater (10.26 vs. 8.52 min/meal; $P < 0.01$) resulting in a greater amount of time spent at the feeder throughout the day (75.28 vs. 61.98 min/d; $P < 0.01$) for NAT steers compared to CONV-Z steers during d0Z-d20Z. Calculated feeding rate was increased by 17.8% for CONV-Z steers compared to NAT steers (0.152 vs. 0.129 kg/min; $P < 0.01$) for the entire feeding period. There was no effect of treatment on calculated day to day variation of feed intake ($P = 0.37$).

### ***Feeding Behaviors – Water Intake***

As previously mentioned, water intake was numerically greater throughout the experiment, with a 2.67 L/d greater intake for NAT steers compared to CONV-Z steers for the entire study (56.26 vs 53.59 L/d; $P < 0.01$). The number of water meals/d was numerically greater for NAT compared to CONV-Z (Table 6.6; 7.20 vs. 6.86 meals/d; $P = 0.35$), this was true for every time period except for d 0Z-20Z were the number of water meals were equal (6.27 vs. 6.27 meals/d; $P = 0.99$) for NAT steers compared to CONV-Z steers. The amount of water consumed/meal did not differ between treatments (7.85 vs. 7.95 L/meal; $P = 0.77$). Even though meal size did not differ, there was an increase in meal length for NAT steers compared to CONV-Z steers (3.23 vs. 2.58 min/meal; $P < 0.01$), resulting in an increase in total time spent at the water bin/d (23.71 vs. 17.80 min/d; $P < 0.01$). The increase in meal length and time spent at water bin/d was consistent throughout the study. Calculated drinking rate was increased by 29.0% for CONV-Z steers compared to NAT steers (3.29 vs. 2.55 L/min; $P < 0.01$). There was no effect of treatment on calculated day to day variation of water intake ($P = 0.62$).

### ***Carcass Characteristics***

The use of efficiency enhancing technologies improved dressing percentage by 2.17 percentage units (Table 6.9; 65.31 vs. 63.14; $P < 0.01$), resulting in a 48 kg improvement in HCW (388 vs. 340 kg; $P < 0.01$) compared to NAT steers. There was no effect of treatment on

12th rib-fat thickness (*P* = 0.73). However, there was a 11.09 cm$^2$ increase in ribeye area (87.25 vs.76.16 cm$^2$; *P* < 0.01) for CONV-Z steers compared to NAT steers, resulting in a numerical increase in USDA Yield Grade (3.19 vs. 3.02; *P* = 0.31) for NAT steers compared to CONV-Z steers. Marbling score was increased for NAT steers compared to CONV-Z steers (504 vs. 410; *P* < 0.01).

## DISCUSSION

As expected, feedlot performance, and USDA Yield Grade were improved with minimal impacts on carcass quality for CONV-Z steers compared to NAT steers. These results are similar to previously published data (Sawyer et al., 2003; Wileman et al., 2009; Cooprider et al., 2011; Maxwell et al., 2014a, and Maxwell et al., 2014b). Interestingly, DMI and ADG was higher in the current study, with minimal impacts on efficiency compared to cohorts as described by Maxwell et al. (2014a). This 6-8% improvement in intake and gain is attributable to the improved environmental conditions due to the shade provided by the building. This demonstrates that the design and functionality of the Insentec feed intake facility did not negatively impact feedlot performance compared to their cohorts fed in outside pens with similar management and diets.

The 45% improvement in ADG and efficiency for CONV-Z compared to NAT in the current study is larger than the 33-38% improvement described by Maxwell et al. (2014a) and the 24-28% improvement described by Maxwell et al. (2014b). This is also true for calculated carcass performance, mostly due to the 0.56 percentage unit larger improvement in dressing percentage for CONV-Z compared to NAT than in the other reported trials. The difference in HCW of 60 kg is greater as reported by Maxwell et al. (2014b) than the 48 kg improvement reported in this study. However, recall the conventional cattle in Maxwell et al. (2014b) received an implant during the stocker-phase. However it is similar to the 46 kg improvement noted by Maxwell et al. (2014a). Similar to data reported by Maxwell et al. (2014a) and (2014b), 12th rib-fat thickness was similar between CONV-Z and NAT cattle. The calculated dietary energy values in this experiment are similar to those calculated by Maxwell et al. (2014a) and (2014b), indicating that the use of technology improves dietary $NE_g$ by 15-30%.

Daily water intakes were substantially higher than those noted by Sexson et al. (2012) of 37.14 L/d and Arias and Mader (2011). Sexson et al. (2012) predicted water intake for yearling steers in the months of May-September to be from 36-40 L/d. However, these differences are expected to be due from the differing weather conditions between Lamar, CO, and Stillwater, OK. In comparison to the published results of 32.4 L/d in the summer of Arias and Mader (2011), the cattle in the current experiment consumed 1.33 kg more feed than those of Arias and Mader (2011), also average maximum temperature was higher in the current study (31.73 °C vs 27.5 °C). Table 6-1 of NRC (2000) suggests that a 454 kg animal on a finishing diet should consume 54.9 L/d when ambient temperature is 26.6 °C. Unexpectedly, water intake was 2.67 L numerically greater for NAT compared to CONV-Z. Although not statistically significant, due to the increased number of water meals/d and a substantial increase in time spent at the water bins, coupled with observed deteriorated pen conditions for NAT compared to CONV-Z, this difference is considered biologically significant. The standard error of water intake is quite large (~ 3.0 L), therefore, 27 animals/treatment are not adequate replication to detect a 5% difference. Throughout the trial, it was observed that the concrete pad was significantly wetter indicating more urination, as no water leaks were noted. Due to the difficulty in measuring water intake, there is no published data related to the effects of technology on water intake. It is hypothesized that the increase in water intake may be due to the NAT cattle attempting to buffer the rumen. Without an ionophore and being fed a high-concentrate diet, the rumen PH will be lower for NAT compared to CONV-Z due to increase lactate production (Nagaraja et al., 1982). Cottee et al. (2004) noted an increase in water consumption in dairy cows exposed to a sub-acute ruminal acidosis challenge for the 3 h period that ruminal pH was the lowest. However, Mullins et al. (2012) noticed no difference in water intake for transition dairy cows with and without monensin.

Furthermore, perhaps the excess protein fed in the diet resulted in an increase in water consumption. Without the use of growth implants, the protein requirements of the NAT cattle should be lower than those of CONV-Z. Galyean (1996) summarized several trials that suggested crude protein requirements increased for cattle receiving growth implants, especially androgen and estrogen combination implants, such as the one in this experiment, compared to non-implanted controls. In this experiment, the level of protein was similar between treatments (19% CP, DM basis). The CP level fed in this experiment is definitely in excess for both treatments. Shaw et al. (2006) reported an increase in water consumption and urinary excretion in pigs fed diets excessive in CP. Further research is needed to investigate the increase in water intake when cattle are fed with no technologies.

Due to this slight increase in water intake, total efficiency, a term defined as total efficiency of all resources used for gain (dry feed, water attributed to feed, and water intake) was increased by 50% for CONV-Z compared to NAT. This total efficiency has not been previously published but would further elucidate the benefits in efficiency enhancing technologies role in environmental sustainability.

One of the goals of this experiment was to examine the effects of CONV-Z and NAT production on feeding behavior. Throughout the study, the CONV-Z animals spent 73 min/d at the feed bin, whereas NAT spent 85 min/d at the feed bin. These results are similar to those reported by Schwartzkopf-Genswein et al. (2011) whom reported a range between 73.4 and 97.8 min/d. Moreover, visits/d were also similar in that Schwartzkopf-Genswein et al. (2011) reported 4.0 to 6.6 visits/d slightly lower than the 7.59 to 8.22 visits/d reported in this study. It is interesting to note that as DOF increased, meals/d and total time spent at the feeder decreased, whereas eating rate increased. Schwartzkopf-Genswein et al. (2011) also noted a decrease in visits/d and an increase in eating rate for cattle on a finishing diet compared to a backgrounding diet with lower roughage level. In this experiment, it is important to note the increase in eating and drinking rate, mostly due to the increase in meal size, as well as fewer meals/d for CONV-Z compared to NAT, suggesting a more aggressive eating and drinking behavior. Data from the current study suggests that there were no differences in daily variation for CONV-Z compared to NAT. Previous data have shown that monensin supplementation reduces feed intake variation (Stock et al., 1995). Mullins et al. (2012) reported no effect of monensin on meals/d or meal length for transition dairy cows, however the authors did note that the decrease in rumen pH was not substantial. Erickson et al. (2003) noted that feeding monensin increased number of meals and decreased feed rate following an acidosis challenge, resulting in a numerically lower pH change and variation in pH for animals fed via clean bunk management. However in a similar bunk management to the one in the current study of ad libitum, no effect of monensin was noted. It is hypothesized that the administration of a combination implant may mask some of the intended effects of monensin due to increasing DMI. Mader et al. (1994) reported an increase in DMI for cattle implanted compared to non-implanted cattle. Also, Maxwell et al. (2014b) reported an increase in DMI for conventional cattle compared to naturals. However, similar to the current study, no difference was noted in DMI between conventional and naturally fed cattle by Maxwell et al. (2014a). Maxwell et al. (2014b) described a more aggressive feeding behavior for CONV-Z compare to NAT, perhaps described by the data in this experiment. Perhaps the NAT cattle quickly adapted to a level of discomfort as described by Forbes (2003) that resulted in more, smaller meals throughout the day to prevent digestive discomfort. It is important to note that there were no changes from the previous time periods on eating or drinking behavior for the CONV-Z cattle when zilpaterol was fed. Furthermore, water intake did not increase drastically compared to the other periods, indicating the cattle experienced no difficulty in dealing with the heat during the period in which zilpaterol was fed.

## CONCLUSIONS

The results of this study further elucidate the advantages of using technology to increase efficiency and enhance production of beef cattle. This study suggests that there are some water use efficiency implications for NAT compared to CONV-Z, however further research is needed to determine the effects of technology use on water intake. Moreover these data suggest that CONV-Z animals possess a more aggressive eating behavior than those of NAT. Limited data are available to fully understand the cause of this, however, the increase in DMI intake due to growth implants and the possibility that NAT animals adapt to the discomfort of digestive upsets caused by over-eating are possible hypotheses. Lastly, results from this study indicate cattle fed zilpaterol do not deviate from normal feeding behaviors and water intake does not exceed that of cattle fed without the use of technologies. However, further research is needed to confirm feeding behavior and water intake of animals on an individual basis.

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**Table 6.1.** Ingredient composition (% DM basis) of diets fed[1]

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

[1] Actual DM formulation calculated based upon As-Is formulations and weekly ingredient DM values.

[2] 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.

[3] 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% 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.

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

**Table 6.2.** Analyzed nutrient composition of diets fed[1]

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

[1] All 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.

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

**Table 6.3.** The effects of treatment on body weights

| | Treatment[1] | | | |
|---|---|---|---|---|
| Item, | NAT | CONV-Z | SE[2] | *P*-value |
| Total head | 27 | 27 | - | |
| Days on feed | 115 | 115 | - | |
| Initial BW[3], kg | 390 | 391 | 2.57 | 0.77 |
| d 28 BW[3], kg | 428 | 443 | 2.92 | <0.01 |
| d 56 BW[3], kg | 467 | 495 | 3.63 | <0.01 |
| d 0 Z BW[3], kg | 505 | 548 | 3.46 | <0.01 |
| d 10 Z BW[3], kg | 514 | 569 | 3.91 | <0.01 |
| d 20 Z BW[3], kg | 526 | 588 | 3.88 | <0.01 |
| Carc. Adj. Final BW[4], kg | 529 | 605 | 6.56 | <0.01 |
| Hot carcass weight, kg | 340 | 388 | 4.21 | <0.01 |

[1] Treatments include 1) Natural – no antibiotics, ionophores, growth implants or beta-agonists (NAT), 2) Conventional w/ zilpaterol – fed tylosin, monensin, received growth implant, fed zilpaterol hydrochloride (87.73 mg/steer last 20 DOF; CONV-Z).

[2] Standard error of the mean (n = 27).

[3] A pencil shrink of 4% was applied.

[4] Carcass adjusted performance data was calculated based upon an average dressing percentage of 64.22%.

**Table 6.4.** The effects of treatment on live feedlot performance

| | Treatment[1] | | | |
|---|---|---|---|---|
| Item | NAT | CONV-Z | SE[2] | *P*-value |
| d 0-28 | | | | |
| Water intake, L/d | 53.03 | 48.51 | 2.83 | 0.14 |
| DMI, kg/d | 10.46 | 10.44 | 0.18 | 0.93 |
| ADG, kg/d | 1.37 | 1.86 | 0.09 | <0.01 |
| G:F, kg/kg | 0.132 | 0.179 | 0.01 | <0.01 |
| Total efficiency[3], kg/kg | 0.022 | 0.031 | 0.001 | <0.01 |
| d 28-56 | | | | |
| Water intake, L/d | 58.63 | 54.86 | 3.70 | 0.27 |
| DMI, kg/d | 10.93 | 10.93 | 0.22 | 0.99 |
| ADG, kg/d | 1.37 | 1.84 | 0.08 | <0.01 |
| G:F, kg/kg | 0.124 | 0.169 | 0.007 | <0.01 |
| Total efficiency[3], kg/kg | 0.019 | 0.028 | 0.002 | <0.01 |
| d 56-0Z | | | | |
| Water intake, L/d | 55.25 | 52.99 | 3.02 | 0.52 |
| DMI, kg/d | 11.43 | 11.41 | 0.18 | 0.94 |
| ADG, kg/d | 1.09 | 1.52 | 0.06 | <0.01 |
| G:F, kg/kg | 0.096 | 0.133 | 0.005 | <0.01 |
| Total efficiency[3], kg/kg | 0.016 | 0.023 | 0.001 | <0.01 |
| d 0Z-20Z | | | | |
| Water intake, L/d | 57.48 | 56.73 | 3.02 | 0.86 |
| DMI, kg/d | 10.49 | 10.59 | 0.26 | 0.71 |
| ADG, kg/d | 1.04 | 1.99 | 0.11 | <0.01 |
| G:F, kg/kg | 0.099 | 0.187 | 0.008 | <0.01 |
| Total efficiency[3], kg/kg | 0.015 | 0.030 | 0.002 | <0.01 |
| d 0-Final | | | | |
| Water intake, L/d | 56.26 | 53.59 | 3.08 | 0.43 |
| DMI, kg/d | 10.90 | 10.90 | 0.16 | 0.97 |
| ADG, kg/d | 1.22 | 1.77 | 0.03 | <0.01 |
| G:F, kg/kg | 0.112 | 0.163 | 0.002 | <0.01 |
| Total efficiency[3], kg/kg | 0.018 | 0.027 | 0.001 | <0.01 |

[1] Treatments include 1) Natural – no antibiotics, ionophores, growth implants or beta-agonists (NAT), 2) Conventional w/ zilpaterol – fed tylosin, monensin, received growth implant, fed zilpaterol hydrochloride (87.73 mg/steer last 20 DOF; CONV-Z).

[2] Standard error of the mean (n = 27).

[3] Total efficiency is calculated as ADG/(DMI+water intake+water attributed in feed intake).

**Table 6.5.** The effects of treatment on feed intake behaviors

| | Treatment[1] | | | |
|---|---|---|---|---|
| Item | NAT | CONV-Z | SE[2] | *P*-value |
| d 0-28 | | | | |
| Meals/d[3] | 9.20 | 8.59 | 0.23 | 0.07 |
| Meal size, kg/meal | 1.15 | 1.24 | 0.03 | 0.07 |
| Meal length, min/meal | 10.78 | 10.49 | 0.40 | 0.60 |
| Eating rate, kg/min | 0.108 | 0.120 | 0.005 | <0.01 |
| Time at feeder, min/d | 97.81 | 88.34 | 3.20 | <0.01 |
| DVI, kg[4] | 1.82 | 1.82 | 0.10 | 0.98 |
| d 28-56 | | | | |
| Meals/d[3] | 8.15 | 7.41 | 0.23 | 0.03 |
| Meal size, kg/meal | 1.36 | 1.51 | 0.04 | 0.01 |
| Meal length, min/meal | 9.53 | 9.19 | 0.37 | 0.52 |
| Eating rate, kg/min | 0.145 | 0.168 | 0.008 | <0.01 |
| Time at feeder, min/d | 76.60 | 66.50 | 3.36 | <0.01 |
| DVI, kg[4] | 1.59 | 1.76 | 0.09 | 0.07 |
| d 56-0Z | | | | |
| Meals/d[3] | 8.05 | 7.08 | 0.21 | <0.01 |
| Meal size, kg/meal | 1.44 | 1.65 | 0.04 | <0.01 |
| Meal length, min/meal | 11.23 | 10.74 | 0.56 | 0.39 |
| Eating rate, kg/min | 0.130 | 0.156 | 0.007 | <0.01 |
| Time at feeder, min/d | 89.28 | 74.37 | 4.00 | <0.01 |
| DVI, kg[4] | 2.04 | 2.10 | 0.19 | 0.65 |
| d 0Z-20Z | | | | |
| Meals/d[3] | 7.47 | 7.49 | 0.30 | 0.95 |
| Meal size, kg/meal | 1.42 | 1.45 | 0.04 | 0.69 |
| Meal length, min/meal | 10.26 | 8.52 | 1.09 | <0.01 |
| Eating rate, kg/min | 0.142 | 0.176 | 0.02 | <0.01 |
| Time at feeder, min/d | 75.28 | 61.98 | 5.70 | <0.01 |
| DVI, kg[4] | 2.00 | 2.04 | 0.10 | 0.81 |
| d 0-Final | | | | |
| Meals/d[3] | 8.22 | 7.59 | 0.19 | 0.03 |
| Meal size, kg/meal | 1.34 | 1.46 | 0.04 | 0.02 |
| Meal length, min/meal | 10.50 | 9.82 | 0.56 | 0.18 |
| Eating rate, kg/min | 0.129 | 0.152 | 0.008 | <0.01 |

|  |  |  |  |  |
|---|---|---|---|---|
| Time at feeder, min/d | 85.36 | 73.19 | 3.93 | <0.01 |
| DVI, kg[4] | 1.87 | 1.94 | 0.11 | 0.37 |

[1] Treatments include 1) Natural – no antibiotics, ionophores, growth implants or beta-agonists (NAT), 2) Conventional w/ zilpaterol – fed tylosin, monensin, received growth implant, fed zilpaterol hydrochloride (87.73 mg/steer last 20 DOF; CONV-Z).

[2] Standard error of the mean (n = 27).

[3] Meals are defined as feeding events within a 5 min period summed together.

[4] DVI is the absolute day to day variation of intake as calculated by Schwartzkopf-Genswein et al. (2011).

**Table 6.6.** The effects of treatment on water intake behaviors

| | Treatment[1] | | | |
|---|---|---|---|---|
| Item | NAT | CONV-Z | SE[2] | *P*-value |
| d 0-28 | | | | |
| Meals/d[3] | 8.21 | 7.80 | 0.67 | 0.36 |
| Meal size, L/meal | 6.53 | 6.38 | 0.29 | 0.64 |
| Meal length, min/meal | 3.46 | 2.86 | 0.40 | 0.01 |
| Drinking rate, L/min | 2.01 | 2.45 | 0.17 | 0.04 |
| Time at water bin, min/d | 29.30 | 22.41 | 2.20 | 0.03 |
| DVI, L[4] | 12.46 | 11.95 | 0.76 | 0.64 |
| d 28-56 | | | | |
| Meals/d[3] | 8.22 | 7.68 | 0.79 | 0.18 |
| Meal size, L/meal | 7.17 | 7.30 | 0.31 | 0.70 |
| Meal length, min/meal | 2.70 | 2.24 | 0.19 | <0.01 |
| Drinking rate, L/min | 2.79 | 3.43 | 0.17 | <0.01 |
| Time at water bin, min/d | 22.68 | 16.99 | 1.37 | <0.01 |
| DVI, L[4] | 10.56 | 10.93 | 0.48 | 0.59 |
| d 56-0Z | | | | |
| Meals/d[3] | 6.59 | 6.22 | 0.48 | 0.31 |
| Meal size, L/meal | 8.44 | 8.70 | 0.30 | 0.55 |
| Meal length, min/meal | 3.40 | 2.55 | 0.16 | <0.01 |
| Drinking rate, L/min | 2.65 | 3.63 | 0.18 | <0.01 |
| Time at water bin, min/d | 22.92 | 16.05 | 1.54 | <0.01 |
| DVI, L[4] | 12.55 | 12.20 | 0.70 | 0.73 |
| d 0Z-20Z | | | | |
| Meals/d[3] | 6.27 | 6.27 | 0.47 | 0.99 |
| Meal size, L/meal | 9.18 | 9.25 | 0.36 | 0.88 |
| Meal length, min/meal | 3.43 | 2.80 | 0.18 | 0.02 |
| Drinking rate, L/min | 2.84 | 3.68 | 0.20 | <0.01 |
| Time at water bin, min/d | 22.06 | 18.16 | 1.80 | 0.13 |
| DVI, L[4] | 12.43 | 11.34 | 0.85 | 0.37 |
| d 0-Final | | | | |
| Meals/d[3] | 7.20 | 6.86 | 0.58 | 0.35 |
| Meal size, L/meal | 7.85 | 7.95 | 0.31 | 0.77 |
| Meal length, min/meal | 3.23 | 2.58 | 0.19 | <0.01 |
| Drinking rate, L/min | 2.55 | 3.29 | 0.16 | <0.01 |

| | | | | |
|---|---|---|---|---|
| Time at water bin, min/d | 23.71 | 17.80 | 1.42 | <0.01 |
| DVI, L[4] | 12.00 | 11.64 | 0.51 | 0.62 |

[1] Treatments include 1) Natural – no antibiotics, ionophores, growth implants or beta-agonists (NAT), 2) Conventional w/ zilpaterol – fed tylosin, monensin, received growth implant, fed zilpaterol hydrochloride (87.73 mg/steer last 20 DOF; CONV-Z).

[2] Standard error of the mean (n = 27).

[3] Meals are defined as feeding events within a 5 min period summed together.

[4] DVI is the absolute day to day variation of intake as calculated by Schwartzkopf-Genswein et al. (2011).

**Table 6.7.** The effects of treatment on carcass feedlot performance

| | Treatment[1] | | | |
|---|---|---|---|---|
| Item | NAT | CONV-Z | SE[2] | *P*-value |
| Total head | 27 | 27 | - | |
| Days on feed | 115 | 115 | - | |
| Carcass adjusted[3] | | | | |
| Final BW, kg | 529 | 605 | 6.56 | <0.01 |
| ADG, kg/d | 1.25 | 1.92 | 0.06 | <0.01 |
| G:F, kg/kg | 0.115 | 0.177 | 0.005 | <0.01 |
| Carcass gain d 0Z-20Z[4] | | | | |
| Pred. HCW, kg | 318 | 345 | 2.18 | <0.01 |
| Gain, kg | 21.56 | 43.21 | 2.72 | <0.01 |
| ADG, kg/d | 0.94 | 1.88 | 0.12 | <0.01 |
| G:F, kg/kg | 0.090 | 0.178 | 0.01 | <0.01 |
| Carcass gain overall[4] | | | | |
| Pred. dress, % | 58.44 | 58.48 | 0.08 | 0.77 |
| Pred. HCW, kg | 228 | 229 | 1.80 | 0.78 |
| ADG, kg/d | 0.83 | 1.18 | 0.03 | <0.01 |
| G:F, kg/kg | 0.076 | 0.109 | 0.003 | <0.01 |

[1] Treatments include 1) Natural – no antibiotics, ionophores, growth implants or beta-agonists (NAT), 2) Conventional w/ zilpaterol – fed tylosin, monensin, received growth implant, fed zilpaterol hydrochloride (87.73 mg/steer last 20 DOF; CONV-Z).

[2] Standard error of the mean (n = 27).

[3] Carcass adjusted performance data were calculated based upon an average dressing percentage of 64.22%.

[4] Predicted HCW is calculated as d 0Z BW x 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.

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

**Table 6.8.** The effects of treatment on retained energy calculations[1]

| | Treatment[2] | | | |
|---|---|---|---|---|
| Item | NAT | CONV-Z | SE[3] | *P*-value |
| Total head | 27 | 27 | - | - |
| Days on feed | 115 | 115 | - | - |
| | | | | |
| d 0Z-20Z $NE_m$, mcal/kg | 1.67 | 2.42 | 0.02 | <0.01 |
| Overall $NE_m$, mcal/kg | 1.64 | 2.00 | 0.02 | <0.01 |
| | | | | |
| d 0Z-20Z $NE_g$, mcal/kg | 1.06 | 1.71 | 0.06 | <0.01 |
| Overall $NE_g$, mcal/kg | 1.03 | 1.34 | 0.02 | <0.01 |

[1] Calculated according to Zinn et al., 1992.

[2] Treatments include 1) Natural – no antibiotics, ionophores, growth implants or beta-agonists (NAT), 2) Conventional w/ zilpaterol – fed tylosin, monensin, received growth implant, fed zilpaterol hydrochloride (87.73 mg/steer last 20 DOF; CONV-Z).

[3] Standard error of the mean (n = 27).

**Table 6.9.** The effects of treatment on carcass characteristics

| | Treatment[1] | | | |
|---|---|---|---|---|
| Item | NAT | CONV-Z | SE[2] | *P*-value |
| Total head | 27 | 27 | - | - |
| HCW, kg | 340 | 388 | 4.21 | <0.01 |
| Dressing percentage, % | 63.14 | 65.31 | 0.41 | <0.01 |
| 12th rib-fat thickness, cm | 1.14 | 1.19 | 0.10 | 0.73 |
| LM area, cm$^2$ | 76.16 | 87.25 | 1.47 | <0.01 |
| USDA Yield Grade | 3.19 | 3.02 | 0.13 | 0.31 |
| Marbling Score[3] | 504 | 410 | 28.72 | <0.01 |

[1] Treatments include 1) Natural – no antibiotics, ionophores, growth implants or beta-agonists (NAT), 2) Conventional w/ zilpaterol – fed tylosin, monensin, received growth implant, fed zilpaterol hydrochloride (87.73 mg/steer last 20 DOF; CONV-Z).

[2] Standard error of the mean (n = 27).

[3] 400 = Small00, 500 = Modest00, 600 = Moderate00.

# CHAPTER VII

# EFFECTS OF TECHNOLOGY USE IN FEEDLOT PRODUCTION SYSTEMS ON CARCASS VALUE AND NET RETURN

**ABSTRACT:** Data collected from 3 feedlot trials were used to determine the effects of conventional and natural feedlot production on carcass value and net return. Experiment 1 used 180 black-hided yearling steers. Steers were either implanted with Component TE-G (**CONV**; Elanco Animal Health, Greenfield, IN) or received no implant (**NAT**) for a grazing phase. After the grazing phase, the cattle were finished. For finishing, the 160 steers were randomized to a 2 x 2 randomized complete block design consisting of the original production system (CONV or NAT), as well as a roughage level treatment (7% diet DM [**LOW**] or 12% diet DM [**HIGH**]). The CONV steers were the animals that received the implant during the grazing phase and were fed 33 mg/kg monensin, 9 mg/kg tylosin, implanted with Component TE-S with Tylan, and fed 90 mg/hd zilpaterol hydrochloride (Zilmax, Merck Animal Health, DeSoto, KS) for the final 20 days on feed. The NAT steers were the animals that did not receive an implant during the grazing phase and were not fed monensin, tylosin, or Zilmax. All cattle were fed for 135 d, and then shipped to Creekstone Farms for slaughter. Experiments 2 and 3 used 390 black-hided crossbred steers randomized to 1 of three treatments. Treatments consisted of the NAT treatment referenced from experiment 1, as well as the CONV treatment with the feeding of Zilmax (CONV-Z) and without the feeding of Zilmax (CONV). The 390 steers used in experiment 2 and 3 were fed for an average of 132 d and were shipped to Creekstone Farms Arkansas City, KS for slaughter. Results of the economic analysis would indicate that base carcass value and Choice/Select spread play a pivotal role in determining carcass value and comparative net return. Price premiums ranging from $58.69/animal to $201.07/animal are needed to offset production costs for NAT animals compared to CONV animals, depending upon diet type, base carcass value, Choice/Select spread, and feed cost. Moreover, data indicate that HCW is the largest determining parameter of carcass value. Therefore, data suggest that producers need to fully evaluate the market climate prior to the initiation of a natural program such that the producer can contract a price premium of substantial value to offset increased cost of production.

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

## INTRODUCTION

The production and sales of organic and natural meat has risen sharply in the last decade. A survey indicated that sales of natural and organic meat rose by 0.7% in 2012 compared to 2011 and accounted for about 537 million pounds sold annually (Power of Meat, 2013). This increase in sales and promotion of natural and organic products persuades some producers to consider producing meat to satisfy these niche markets. Animal performance studies indicate a large decrease in animal performance and saleable product for these natural and organic systems compared to conventional production (Wileman et al., 2009; Cooprider et al., 2011; Maxwell et al., 2014a; Maxwell et al., 2014b; Maxwell et al., 2014c). This decrease in performance results in the need for price premiums for these products to offset the cost of production to make these production strategies economical. A survey completed by Springer et al. (2009) indicated that companies purchasing natural cattle were willing to pay a premium. However, those premiums ranged from $0.25 to $15.75/45.4 kg with an average of $6.51/45.4 kg on a live basis, resulting in an average premium of about $84.63/animal. Therefore, the objective of this analysis was to utilize data from recently completed beef production trials to estimate the price premiums needed to offset production costs of natural beef production compared to conventional practices.

## MATERIALS AND METHODS

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

### *Cattle Management and Treatment Structure*

Data for this analysis were obtained using the performance and carcass results of Maxwell et al. (2014a; Year I; Chapter III), Maxwell et al. (2014b; Year II; Chapter IV) and Maxwell et al. (2014c; Year II; Chapter IV) on an individual animal basis. Maxwell et al. (2014a; Year I) used 180 black-hided yearling steers from a single ranch in western Oklahoma to determine the effects of technology using conventional and natural production programs with differing roughage levels on annual pasture performance, feedlot performance, and carcass characteristics. During November, 2011, the 180 steers were divided into 2 treatments. Steers were either implanted with Component TE-G (**CONV**; Elanco Animal Health, Greenfield, IN) or received no implant (**NAT**). The steers grazed for 109 d on annual cool season forage. After the 109 d grazing phase, the cattle were transported to Willard Sparks Beef Research Center (Oklahoma State University, Stillwater, OK) for the finishing phase of the experiment. Upon arrival at the feedlot, the cattle were weighed and 160 steers were randomized to a 2 x 2 randomized complete block design consisting of the original production system (CONV or NAT), as well as a roughage level treatment (7% diet DM [**LOW**] or 12% diet DM [**HIGH**]). The CONV steers were the animals that received the implant during the grazing phase and were fed 33 mg/kg monensin, 9 mg/kg tylosin, implanted with Component TE-S with Tylan, and fed 90 mg/hd zilpaterol hydrochloride (Zilmax, Merck Animal Health, DeSoto, KS) for the final 20 days on feed. The NAT steers were the animals that did not receive an implant during the grazing phase, and were not fed monensin, tylosin, or Zilmax. These steers were subjected to the Creekstone Farms All-Natural Black Angus program (Arkansas, City, KS). The steers were sorted into 32 study pens (5 steers/pen; 8 replications/treatment; 40 animals/treatment). All cattle were fed for 135 d, and then shipped to Creekstone Farms for slaughter. Carcass data were collected by Creekstone personnel using an E + V Vision Grading camera (VBG2000, E + V Technology, Oranienbury, Germany). Further details regarding diets, and detailed description of results was reported by Maxwell et al. (2014a).

Maxwell et al. (2014b and 2014c; Year 2) used 390 black-hided crossbred steers from South Dakota and Nebraska origin. The cattle arrived at Willard Sparks Beef Research Center on April 26 and 29, 2013. These cattle were weighed and randomized to 1 of three treatments. Treatments consisted of the NAT treatment referenced from year 1, as well as the CONV treatment with the feeding of Zilmax (CONV-Z) and without the feeding of Zilmax (CONV). All three treatments were fed the same diets as in year 1, with 7% diet DM roughage level. The cattle described in Maxwell et al. (2014b) were fed in 24 pens (8 pens/treatment; 14 steers/pen; 112 steers/treatment). Maxwell et al. (2014c) utilized only the cattle from CONV-Z and NAT treatments and fed them in an individual intake facility (4 pens; 2 replications/treatment; 13-14 animals/pen; 27 animals/treatment). The 390 steers used in year 2 were fed for an average of 132 d, and were shipped to Creekstone Farms Arkansas City, KS for slaughter. Carcass data were collected as previously mentioned.

### *Economic Analysis*

The data reported in this paper were analyzed separately for the two years (160 steers – Year 1 and 390 steers – Year 2). For both years, body weights, carcass characteristics and health records were collected individually for all cattle. Dry matter intake records were summarized and recorded on a pen basis, however, for this analysis, all animals within each respective pen were assigned an intake value to the average of the pen for feed cost calculations. Table 7.1 shows the values assigned to the animals for each respective year. For year 1, feeder calf value (FdrPr) was calculated based upon individual animal BW at the initiation of the pasture phase and the price structure obtained from the report KO_LS795 (AMS.USDA.GOV) dated November 16, 2011. Cost of gain for the pasture phase was valued at $0.65/0.45 kg BW gain (WhtCost). For the feedlot phase, feed cost was based at $300/907.2 kg (FdCost; DM, basis). The CONV cattle were assigned a feed technology cost of $36.51/steer to account for cost of Rumensin, Tylan, and Zilmax (FdTech), as well as an additional $3.60/steer for the implants (Implant). Base carcass price was $180/45.4 kg for 2012 data (Year 1).

For Year 2 (2013), feeder calf price (FdrPR) was calculated based upon BW taken upon arrival at the feedlot, and price structure was determined by the report KO_LS795 dated May 15, 2013. There was no wheat cost for year 2, feed cost was the same as in year 1 (FdCost; $300/907.2 kg [DM, basis]). Feed technology cost was $36.36 for the CONV-Z cattle, $6.36 for the CONV cattle and $0 for the NAT cattle (FdTech). Implant cost was $8.25 for both the CONV and CONV-Z cattle (Implant), and base carcass price was valued at $200/45.4 kg.

Three separate sensitivity analysis were conducted. Individual carcass value and net return was calculated based upon 5 carcass grids, 5 feed costs, and 5 base carcass values. Table 7.2 shows the premiums and discounts used for USDA Quality Grade (QGprem) and USDA Yield Grade (YGprem) calculations used for the sensitivity analysis due to carcass grids. A HCW discount of $22.50/45.4 kg was utilized on all grids for HCW heavier than 476 kg (HCWprem). For the feed cost sensitivity analysis, the carcass grid with the $10 USDA Choice/Select spread was used, as well as the base carcass price of $180 and $200 for year 1 and year 2, respectively, holding all other variables constant. For the base carcass price sensitivity analysis, the carcass grid with the $10 Choice/Select spread was used as well as the feed cost of $300/902.7 kg (DM, basis) holding all other variables constant. For year 1 (2012) carcass value and net return were calculated as:

$$Carc.Val.(CXV) = \frac{180.00 + QGprem + YGprem + HCWprem}{100} * HCW \tag{1}$$

$$Net\ Return = \text{CXV-(FdrPr+FdCost+Implant+FdTech+WhtCost+TrtCost)} \tag{2}$$

For year 2 (2013) carcass value and net return were calculated as:

$$Carc.Val.(CXV) = \frac{200.00 + QGprem + YGprem + HCWprem}{100} * HCW \tag{3}$$

$$Net\ Return = \text{CXV-(FdrPr+FdCost+Implant+FdTech+TrtCost)} \tag{4}$$

The economic models were estimated using PROC REG (SAS 9.3; SAS Inst. Cary, NC) as shown below. Carcass value and net return were estimated using CONV-LOW and CONV-Z as the base treatments for Year 1 and Year 2, respectively.

$$\begin{aligned} Carc.Val._{Conv-Low} \\ &= \beta_0 + \beta_1 NAT - LOW \\ &+ \beta_2 NAT - HIGH\ + \beta_3 CONV - HIGH \end{aligned} \tag{5}$$

$$Carc.Val._{Conv-Z} = \beta_0 + \beta_1 NAT + \beta_2 CON \tag{6}$$

$$\begin{aligned} Net\ Return_{Conv-Low} \\ &= \beta_0 + \beta_1 NAT - LOW \\ &+ \beta_2 NAT - HIGH\ + \beta_3 CONV - HIGH \end{aligned} \tag{7}$$

$$Net\ Return_{Conv-Z} = \beta_0 + \beta_1 NAT + \beta_2 CON \tag{8}$$

These treatments were chosen because they would represent the most conventional diets used in the feedlot industry. The other treatments were analyzed in the model and removed if deemed not statistically significant ($P \leq 0.05$). Pearson correlation coefficients were determined using PROC CORR (SAS 9.3) for HCW, marbling score, 12th rib-fat thickness, and longissimus area and their relationship with carcass value and net return. Animals that died over the course of the study were not used in this analysis. Animals removed from the study for other reasons were still included in this analysis.

## RESULTS

The input costs associated with each treatment are shown in tables 7.3 and 7.4 for Year 1 and Year 2, respectively. Health treatment cost was not different due to treatment for either year (Year 1 - $0.89/steer; Year 2 - $0.21/steer), as there were no significant health challenges noted in either year. In year 1, there were 5 mortalities (2-CONV/HIGH, 2-CONV/LOW, and 1-NAT/HIGH) during the course of the experiment and 3 steers removed for lameness (1-CONV/LOW, 1-NAT/LOW, and 1-CONV/HIGH). In year 2, 3 steers died (1-NAT and 2-CONV-Z) and 2 steers were removed for lameness (1-CONV and 1-NAT). The differences in feed cost are mostly due to the added cost of technologies in the rations for the conventionally fed cattle, as there was only a small (~4%) increase in dry matter intake for conventional cattle compared to natural cattle. For year 1, the total cost of production was $108.90/steer greater for CONV than NAT due to greater DMI, cost of technologies, and increased cost of pasture due to increased gains. For Year 2, the CONV-Z cattle had the highest cost of production due to the cost of Zilmax.

### *Choice/Select Spread Sensitivity Analysis*

The results for the effects of treatment and differing carcass grids are shown in tables 7.5 and 7.6 for Year 1 and Year 2, respectively. For Year 1, NAT-LOW and NAT-HIGH had significant variables in all models, however, CONV-HIGH was equal to that of CONV-LOW. As expected, base carcass value increased from $1612.26/steer to $1652.24/steer as Choice/Select spread narrowed from $20 to $0.00. For every $5.00 decrease in Choice/Select spread, carcass value increased $11.70/steer from $20.00 spread to $5.00 spread. However, carcass value only increased $4.87/steer when Choice/Select spread narrowed from $5.00 to $0.00. Across all 5 grids, the estimated carcass value for NAT-LOW was $181.31/steer lower than the conventional cattle, and NAT-HIGH was $248.61/steer lower than the conventional cattle. It is interesting to note, that the difference in roughage level (12% vs. 7%), changed net return by an average of $67.30/steer for the naturals, but was not different in the conventional cattle. Based upon industry standards, nutritionists would typically recommend the HIGH roughage level for NAT cattle to prevent digestive upsets. This difference in carcass value, translates to an average lower net return of $77.20/animal for NAT-LOW compared to conventional, and $155.87 lower net return for NAT-HIGH compared to conventional. As Choice/Select spread narrowed from $20 to $5, the difference in net return for NAT-LOW increased by $6.76/steer relative to conventional production. However, as the Choice/Select spread narrowed from $5.00 to $0.00, the relative difference increased by $32.63/steer for NAT-LOW relative to conventional production. Similarly, as Choice/Select spread narrowed from $20 to $5, the difference in net return for NAT-HIGH increased by $7.40/steer relative to conventional production, but as the spread narrowed from $5.00 to 0.00, the difference increased by $44.51/steer. These results indicate that, based upon roughage level and Choice/Select spread, the premium needed for natural cattle to offset the cost of production and decreased net returns of conventional cattle ranges from $58.69/steer to $201.07/steer.

For Year 2, there was very little difference noted between the CONV and CONV-Z treatments in regards to carcass value and net return (Table 7.6). This is due to the less than expected response when Zilmax was fed as discussed by Maxwell et al. (2014b). For carcass value, when Choice/Select spread became $0, CON, was a statistically significant parameter in the model, indicating $27.99/steer lower carcass value compared to CONV-Z, however this was not true for all other Choice/Select spreads. Similar to Year 1, as Choice/Select spread narrowed, carcass value increased. As Choice/Select spread narrowed to $5.00, carcass value increased by $6.76/steer, and increased by $12.09/steer as Choice/Select spread reached $0.00. The difference in net return for NAT, relative to CONV-Z increased by about $3.20/steer for every $5.00 decrease in Choice/Select spread, and increased by $20.44 as Choice/Select spread narrowed from $5.00 to $0.00. For net return, the conventional cattle not fed Zilmax (CON) showed about a $30 increase in net return when Choice/Select spread was $20.00 or $15.00 compared to CONV-Z. However, the difference was not significant as Choice/Select spread decreased below $15.00. The relative difference in net return for NAT compared to CONV-Z was $116.43/steer at a Choice/Select spread of $20.00, but rose to $147.68/steer at a Choice/Select spread of $0.00, with the average difference being $132.53/steer. These results indicate that the premium needed for natural cattle to offset the cost of production and decreased net returns of conventional cattle ranges from $116.43/steer to $147.68/steer, varying with price grid.

### *Feed Cost Sensitivity Analysis*

Table 7.7 and 7.8 show the effects of varying feed costs on net return for Year 1 and Year 2, respectively. Increasing feed costs does not impact net return in this instance as all other parameters were held constant. Data from Year 1 suggest that increasing feed cost does not have a large effect on net return. Maxwell et al. (2014a) noted an increase in DMI for the conventionally fed cattle compared to the naturally fed cattle. When using a base carcass price of $180 and a $10 Choice/Select spread, an increase in feed cost from $250 to $350/907.2 kg decreased relative net return by $11.70 for NAT-LOW compared to CONV[($77.53/steer)-$(65.83/steer)], a change of $2.93/steer for every $25 increase in feed cost. Similarly, that same increase in feed cost decreased relative net return by $9.61/animal for NAT-HIGH compared to CONV [($153.30/steer)-$(143.69/steer)], a change of $2.40/steer for every $25 increase in feed cost. In summary, as feed costs increased from $250 to $350/907.2 kg, net return improved for NAT cattle relative to CONV cattle. Cattle fed NAT-LOW would need a $77.53 premium to offset costs when feed costs were $250.00/907.2 kg compared to $65.83 when feed costs were $350/907.2 kg, based upon a base carcass price of $180 and a $10 Choice/Select spread. Moreover, cattle fed NAT-HIGH would need a $153.30 premium to offset costs when feed costs were $250.00/907.2 kg compared to $143.69 when feed costs were $350/907.2 kg, based upon a base carcass price of $180 and a $10 Choice/Select spread.

For Year 2 (table 7.8) there was even less of an impact as relative net return for NAT only changed by $3.53/animal as feed costs increased from $250 to $350/907.2 kg. For every $25 increase in feed cost, net return for NAT relative to CONV improved by $0.88. Indicating that when feed costs were $250/907. 2kg, a $138.67/steer premium would be needed to offset production costs. However, when feed costs were $350/907.2 kg, a $135.14/steer premium would be needed to offset production costs compared to CONV based upon a base carcass price of $200 and a $10 Choice/Select spread.

### *Base Carcass Price Sensitivity Analysis*

Table 7.9 and 7.10 show the effects of altering base carcass price on carcass value and net return, a constant ration price of $300/907.2 kg and a Choice/Select spread of $10 was used. For Year 1, there was an increase in carcass value as base carcass price increased from $160/45.4 kg to $200/ 45.4kg. For the CONV cattle carcass value improved from $1450.27/steer to $1820.99/steer an increase of $92.68/animal for every $10 increase in base carcass price. As expected the premium needed for NAT-LOW to offset increased production costs increased from $48.47 to $94.89/animal compared to CONV and increased from $120.34 to $176.66/animal for NAT-HIGH compared to CONV. For NAT-LOW, the needed premium increased by $11.61/animal for every $10 increase in base carcass price and $14.08/animal for NAT-HIGH.

For Year 2, CONV carcass value improved from $1548.88 to $1892.52 as base carcass price increased from $180 to $220 (Table 7.10). The premium needed for NAT to offset production costs rose from $106.71/animal to $155.79/animal as base carcass price increased from $180 to $220, a $12.27 increase in premium for every $10 increase in base carcass value.

### *Parameters Related to Carcass Value and Net Return*

Table 7.11 shows the Pearson correlation coefficients for parameters related to carcass value and net return. Data from both years were combined for this analysis. Hot carcass weight had the highest coefficient for both carcass value and net return, 0.74 and 0.46, respectively. For carcass value, ribeye area showed to have the next highest correlation coefficient at 0.36, followed by 12th rib-fat thickness (-0.18), marbling score (0.16), and USDA YG (-0.15). For net return, 12th rib-fat thickness had the second highest correlation value (-0.33), followed by marbling score (0.21), USDA YG (-0.21), and ribeye area (~0.20). Carcass traits, such as marbling score, USDA Yield Grade, and 12th rib-fat thickness play a much less pivotal role in determining the value and net return of cattle, compared to red meat yield indicators such as HCW and longissimus area.

## DISCUSSION

As shown in the results, many variables and management decisions play a pivotal role in determining carcass value and net return. Few published studies have been done examining the price premiums needed to offset the cost of production for natural cattle compared to conventionally fed cattle. Lawrence and Ibarburu (2007) performed a comprehensive analysis of the beef industry and the effects of removing technologies would have on breakeven prices and production costs. The authors noted that removing implants in the stocker phase would increase breakeven by 2.31% and increase cost by $18.19/steer for the stocker phase. Moreover, if implants were removed from feedlot production, cost would increase $68.59/steer, ionophore removal would increase cost $12.43/animal, and beta agonist removal would increase costs by $13.02/animal. If all technologies were removed from the feedlot phase, breakeven would be increased 11.99%, and cost would increase $126.09/animal. For the entire beef sector (cow/calf, stocker and finishing) removing technologies would increase breakeven price by 36.63% and increase cost $365.65/animal (Lawrence and Ibarburu, 2007). Moreover, the authors estimated that after 5 years post technology removal, the cost of beef at retail would increase by 13.10%. Wileman et al. (2009) estimated that implanting animals in the feedlot phase would lower cost of production by $77/animal compared to a non-implanted conventionally fed animal and by $349/animal lower production cost compared to an organically reared animal. Cooprider et al. (2011) estimated natural production increased cost of gain by 20.5% compared to conventionally fed animals (using ionophores, implants and beta-agonists [BAA]). Stackhouse et al. (2012) noted that implant and ionophore use increased profit by $0.07/kg HCW and BAA increased profit by an additional $0.04/kg HCW when a stocker system was used in Angus production. Schroeder and Tonsor (2011) estimated that the use of the beta-agonist Zilmax increased net returns by $21/animal to cattle feeders. When accounting for weighted averages of effects of Optaflexx and Zilmax, Johnson et al. (2014) estimated a decrease in cost of production of $42.47/animal with the use of beta agonists to the feedlot industry. Lastly, Duckett and Pratt (2014) estimated the use of a single estrogenic implant would improve returns by $54.02/animal, whereas the use of 2 combination (estrogenic and androgenic) implants would increase return by $218.58/animal. The average of all typical implant protocols would improve return by $102.62/animal (Duckett and Pratt, 2014).

Current results agree with these previously published results that the removal of all technologies increases production cost by approximately $150/animal. Base carcass price and Choice/Select spread play a huge role in determining profit differences, and in most cases it is unlikely that a producer could contract a premium prior to these management decision, increasing risk of producing natural cattle. As Choice/Select spread widens, the premium needed for natural cattle is lowered, but as base carcass price increases, the premium needed for natural cattle is raised. Results indicated that lowering roughage level on natural cattle will decrease cost of production and increase net returns, but more data is needed to determine the effects of the lowered roughage level on the number of digestive mortalities in a large pen setting.

## CONCLUSIONS

Results from this analysis would indicate that there is a substantial decrease in carcass value for NAT cattle compared to CONV cattle, mostly due to the decrease in HCW. Therefore, premiums are needed from the packer to offset this decrease in carcass value to equalize net return compared to conventional production. Results from Year 1 would indicate that it is more cost effective to produce NAT cattle using a lower roughage level (7% diet DM), however more research is needed to confirm these results in a large commercial setting. As mentioned previously, the use of beta-agonists typically increase net return by \$30-\$40 animal, however that was not found in this study. From the sensitivity analyses performed, it becomes evident that the change in base carcass price invokes the largest change in net return, followed by Choice/Select spread, and then feed costs. This is not a surprise due to the large differences in HCW between production groups. However, conventional production decreases the number of carcasses grading USDA Choice and becomes an important factor affecting net return. Based upon the data from this analysis, roughage level needs to be considered, and the ability to implant cattle in a grazing program prior to finishing. However, using data from the from both studies, a premium of no less than \$140-150.00/animal is required for natural cattle to have equal net returns to those fed conventionally with a \$10 Choice/Select spread.

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**Table 7.1.** The values assigned to costs during the study period per year

| | Year | |
|---|---|---|
| Item | 2012 | 2013 |
| Feeder steer price (FdrPr) \$/steer[1] | 862.74 | 1060.40 |
| Wheat cost (Whtcost), \$/0.45 kg gain | 0.65 | - |
| Feed cost (FdCost), \$/907.2 kg (DM, basis) [2] | 300.00 | 300.00 |
| Feed tech cost (FdTech), \$/steer[3] | 36.51 | 36.36 |
| Implant cost, \$/steer | 3.60 | 8.25 |
| Base carcass price, \$/45.4kg[5] | 180.00 | 200.00 |

[1] For 2012, price was calculated based upon BW at beginning of pasture phase, price structure was obtained from KO_LS795 Nov, 16, 2011. For 2013, price was calculated based upon BW at beginning of feedlot phase, price struction was obtained from KO_LS795 May 15, 2013.

[2] Feed price of \$300/907.2 kg (DM, basis) was similar to commercial ration costs at time of study.

[3] Inlcudes cost of Rumensin, Tylan and Zilmax (Rumensin and Tylan charged at \$0.0482/hd/d, and Zilmax -\$30/hd

feeding Zilmax at 90 mg/hd/d for 20 d prior to slaughter with a 3 d withdrawal

[5] Base price was determined based on the week cattle were harvested.

**Table 7.2.** The premiums/discounts used for calculating carcass value based upon individual animal carcass traits, ($/45.4kg)[1]

| | Choice/Select Spread | | | | |
|---|---|---|---|---|---|
| Item | $20.00 C/S[2] | $15.00 C/S[3] | $10.00 C/S[4] | $5.00 C/S[5] | $0.00 C/S[6] |
| USDA Quality Grade ($/45.4kg) | | | | | |
| Prime | 15.25 | 15.11 | 15.25 | 15.61 | 7.68 |
| Avg. Choice + | 4.00 | 3.88 | 3.63 | 3.13 | 2.42 |
| Choice | 0 | 0 | 0 | 0 | 0 |
| Select | (20.09) | (15.18) | (10.18) | (5.00) | (1.22) |
| Standard | (29.33) | (26.58) | (24.17) | (21.08) | (13.89) |
| USDA Yield Grade ($/45.4kg) | | | | | |
| ≤1.9 | 3.58 | 3.58 | 3.58 | 3.38 | 2.73 |
| 2.0-2.9 | 1.66 | 1.66 | 1.62 | 1.62 | 1.14 |
| 3.0-3.9 | 0 | 0 | 0 | 0 | 0 |
| 4.0-4.9 | (11.23) | (11.23) | (11.38) | (11.38) | (12.45) |
| >4.9 | (16.46) | (16.46) | (17.46) | (17.46) | (18.45) |
| HCW > 476 kg ($/45.4kg) | (22.50) | (22.50) | (22.50) | (22.50) | (22.50) |

[1] Data in this table show the premiums and discounts used to calculate carcass value. Same heavy weight discount was used for all grids.

[2] $20.00/45.4 kg Choice-Select spread. Report LM_CT115 AMS.USDA.GOV 12/10/2012.

[3] $15.00/45.4 kg Choice-Select spread. Report LM_CT115 AMS.USDA.GOV 12/31/2012.

[4] $10.00/45.4 kg Choice-Select spread. Report LM_CT115 AMS.USDA.GOV 09/10/2012.

[5] $5.00/45.4 kg Choice-Select spread. Report LM_CT115 AMS.USDA.GOV 05/07/2012.

[6] $0.00/45.4 kg Choice-Select spread. Report LM_CT115 AMS.USDA.GOV 04/13/2009.

**Table 7.3.** The input costs associated with each treatment for Year 1

| | Treatment | | | | | |
|---|---|---|---|---|---|---|
| Item | NAT-LOW | NAT-HIGH | CONV-LOW | CONV-HIGH | SE | *P*-value |
| Feeder price, \$/steer | 854.59 | 867.41 | 866.69 | 862.28 | 32.42 | 0.55 |
| Wheat cost, \$/steer | $174.67^{a}$ | $165.25^{a}$ | $199.03^{b}$ | $202.6^{b}$ | 14.96 | <0.01 |
| Feed cost, \$/steer | $488.76^{a}$ | $494.71^{a}$ | $554.76^{b}$ | $569.41^{c}$ | 18.86 | <0.01 |
| Health treatment cost, \$/steer | 0.90 | 0.26 | 0.70 | 1.68 | 0.52 | 0.21 |
| Implant cost, \$/steer | 0 | 0 | 3.60 | 3.60 | - | - |
| Total cost, \$/steer | $1518.92^{a}$ | $1527.64^{a}$ | $1624.77^{b}$ | $1639.59^{b}$ | 64.95 | <0.01 |

$^{a,b,c}$Means without a common superscript differ ($P < 0.05$).

**Table 7.4.** The input costs associated with each treatment for Year 2

| | Treatment | | | | |
|---|---|---|---|---|---|
| Item | NAT | CONV | CONV-Z | SE | *P*-value |
| Feeder price, \$/steer | 1060.53 | 1058.48 | 1062.19 | 8.75 | 0.45 |
| Feed cost, \$/steer | 443.24$^{a}$ | 452.31$^{b}$ | 490.35$^{c}$ | 15.56 | <0.01 |
| Health treatment cost, \$/steer | 0.23 | 0.26 | 0.15 | 0.15 | 0.88 |
| Implant cost, \$/steer | 0 | 8.25 | 8.25 | - | - |
| Total cost, \$/steer | 1504.00$^{a}$ | 1519.38$^{b}$ | 1561.02$^{c}$ | 14.85 | <0.01 |

$^{a,b,c}$Means without a common superscript differ ($P < 0.05$).

**Table 7.5.** Estimated carcass value and net return of production systems in Year 1[1]

| | Choice/Select Spread ($/45.4kg) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $20.00 C/S | | $15.00 C/S | | $10.00 C/S | | $5.00 C/S | | $0.00 C/S | |
| Item | Estimate | SE | Estimate | SE | Estimate | SE | Estimate | SE | Estimate | SE |
| Carcass value ($/cx) | | | | | | | | | | |
| Intercept | 1612.26 | 15.11 | 1624.09 | 14.19 | 1635.63 | 13.51 | 1647.34 | 13.08 | 1652.24 | 12.90 |
| NAT-LOW | (167.48) | 25.94 | (173.84) | 24.37 | (180.47) | 23.21 | (187.77) | 22.46 | (196.97) | 22.15 |
| NAT-HIGH | (232.40) | 25.94 | (239.81) | 24.37 | (247.98) | 23.21 | (256.05) | 22.46 | (266.80) | 22.15 |
| Net return ($/steer) | | | | | | | | | | |
| Intercept[2] | (15.50) | 13.33 | (3.67) | 12.24 | 7.86 | 11.42 | 19.58 | 10.88 | 223.26 | 11.09 |
| NAT-LOW | (58.69) | 22.89 | (65.05) | 21.02 | (71.68) | 19.61 | (78.98) | 18.67 | (111.61) | 19.05 |
| NAT-HIGH | (132.92) | 22.89 | (140.32) | 21.02 | (148.50) | 19.61 | (156.56) | 18.67 | (201.07) | 19.05 |

[1] Data in this table show the estimated carcass value and net return of production systems in Year 1 with a varying C/S Spread, a base carcass price of $180 was used and a feed cost base of $300.00.. For the model, CONV-LOW was considered as base. Treatments are defined as Natural (NAT) vs. Conventional (CONV) and 7% (LOW) and 12% (HIGH) dietary DM roughage inclusion level. Unless otherwise noted by a superscript, all parameters were significant $P \leq 0.05$.

[2] Net return intercept P-values, were 0.25, 0.76, 0.49, 0.07, and 0.01.

**Table 7.6.** Estimated carcass value and net return of production systems in Year 2[1]

| | Choice/Select Spread ($/45.4kg) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $20.00 C/S | | $15.00 C/S | | $10.00 C/S | | $5.00 C/S | | $0.00 C/S | |
| Item | Estimate | SE | Estimate | SE | Estimate | SE | Estimate | SE | Estimate | SE |
| Carcass value ($/cx) | | | | | | | | | | |
| Intercept | 1707.22 | 7.92 | 1714.10 | 7.42 | 1720.70 | 6.99 | 1727.25 | 6.66 | 1739.34 | 8.33 |
| NAT | (170.70) | 13.26 | (173.93) | 12.42 | (176.96) | 11.71 | (179.89) | 11.15 | (200.33) | 11.75 |
| CONV | - | - | - | - | - | - | - | - | (27.99) | 12.41 |
| Net return ($/steer) | | | | | | | | | | |
| Intercept | 148.58 | 9.54 | 157.67 | 8.83 | 176.27 | 6.12 | 182.81 | 5.79 | 182.32 | 5.26 |
| NAT | (116.43) | 13.46 | (121.87) | 11.63 | (136.91) | 10.25 | (139.82) | 9.68 | (147.68) | 8.81 |
| CONV | 32.76 | 14.23 | 27.47 | 12.32 | - | - | - | - | - | - |

[1] Data in this table show the estimated carcass value and net return of production systems in Year 1I with a varying C/S Spread, a base carcass price of $200 was used and a feed cost base of $300.00. For the model, CONV-Z was considered as base. Treatments are defined as Natural (NAT) vs. Conventional (CONV) vs. Conventional w/ Zilmax (CONV-Z) All parameters were significant $P \leq 0.05$.

**Table 7.7.** Estimated carcass value and net return of production systems in Year 1 with varying feed costs[1]

| | Ration Cost, $/907.2 kg (DM, basis) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $250 | | $275 | | $300 | | $325 | | $350 | |
| Item | Estimate | SE | Estimate | SE | Estimate | SE | Estimate | SE | Estimate | SE |
| Carcass value ($/cx) | | | | | | | | | | |
| Intercept | 1635.63 | 13.51 | 1635.63 | 13.51 | 1635.63 | 13.51 | 1635.63 | 13.51 | 1635.63 | 13.51 |
| NAT-LOW | (180.47) | 23.21 | (180.47) | 23.21 | (180.47) | 23.21 | (180.47) | 23.21 | (180.47) | 23.21 |
| NAT-HIGH | (247.98) | 23.21 | (247.98) | 23.21 | (247.98) | 23.21 | (247.98) | 23.21 | (247.98) | 23.21 |
| Net return ($/steer) | | | | | | | | | | |
| Intercept | 95.21 | 11.43 | 51.53 | 11.42 | 7.86 | 11.42 | (35.82) | 11.42 | (79.49) | 11.43 |
| NAT-LOW | (77.53) | 19.62 | (74.61) | 19.61 | (71.68) | 19.61 | (68.75) | 19.62 | (65.83) | 19.63 |
| NAT-HIGH | (153.30) | 19.62 | (150.90) | 19.61 | (148.50) | 19.61 | (146.09) | 19.62 | (143.69) | 19.63 |

[1] Data in this table show the estimated carcass value and net return of production systems in Year 1 for differing ration costs based upon a $10 C/S and a carcass base of $180.00. For the model, CONV-LOW was considered as base. Treatments are defined as Natural (NAT) vs. Conventional (CONV) and 7% (LOW) and 12% (HIGH) dietary DM roughage inclusion level. Unless otherwise noted by a superscript, all parameters were significant $P \leq 0.05$.

**Table 7.8.** Estimated carcass value and net return of production systems in Year 2 with varying feed costs[1]

| | Ration Cost, $/907.2 kg (DM, basis) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $250 | | $275 | | $300 | | $325 | | $350 | |
| Item | Estimate | SE | Estimate | SE | Estimate | SE | Estimate | SE | Estimate | SE |
| Carcass value ($/cx) | | | | | | | | | | |
| Intercept | 1720.70 | 6.99 | 1720.70 | 6.99 | 1720.70 | 6.99 | 1720.70 | 6.99 | 1720.70 | 6.99 |
| NAT | (176.96) | 11.71 | (176.96) | 11.71 | (176.96) | 11.71 | (176.96) | 11.71 | (176.96) | 11.71 |
| CONV | - | - | - | - | - | - | - | - | - | - |
| Net return ($/steer) | | | | | | | | | | |
| Intercept | 251.96 | 6.11 | 214.11 | 6.11 | 176.27 | 6.12 | 138.43 | 6.14 | 100.58 | 6.18 |
| NAT | (138.67) | 10.24 | (137.79) | 10.24 | (136.91) | 10.25 | (136.02) | 10.29 | (135.14) | 10.34 |
| CONV | - | - | - | - | - | - | - | - | - | - |

[1] Data in this table show the estimated carcass value and net return of production systems in Year 1I for differing ration costs based upon a $10 C/S and a carcass base of $200.00. For the model, CONV-Z was considered as base. Treatments are defined as Natural (NAT) vs. Conventional (CONV) vs. Conventional w/ Zilmax (CONV-Z). All parameters were significant $P \leq 0.05$.

**Table 7.9.** Estimated carcass value and net return of production systems in Year 1 with varying base carcass price[1]

| | Base Carcass Price ($/45.4kg) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $160 | | $170 | | $180 | | $190 | | $200 | |
| Item | Estimate | SE | Estimate | SE | Estimate | SE | Estimate | SE | Estimate | SE |
| Carcass value ($/cx) | | | | | | | | | | |
| Intercept | 1450.27 | 12.34 | 1542.95 | 12.92 | 1635.63 | 13.51 | 1728.31 | 14.12 | 1820.99 | 14.74 |
| NAT-LOW | (157.26) | 21.20 | (168.86) | 22.19 | (180.47) | 23.21 | (192.08) | 24.25 | (203.68) | 25.32 |
| NAT-HIGH | (219.82 | 21.20 | (233.90) | 22.19 | (247.98) | 23.21 | (262.06) | 24.25 | (276.14) | 25.32 |
| Net return ($/steer) | | | | | | | | | | |
| Intercept | (177.50) | 10.91 | (84.82) | 11.14 | 7.86 | 11.42 | 100.54 | 11.74 | 193.22 | 12.10 |
| NAT-LOW | (48.47) | 18.72 | (60.07) | 19.13 | (71.68) | 19.61 | (83.28) | 20.16 | (94.89) | 20.78 |
| NAT-HIGH | (120.34) | 18.73 | (134.42) | 19.13 | (148.50) | 19.61 | (162.58) | 20.16 | (176.66) | 20.78 |

[1] Data in this table show the estimated carcass value and net return of production systems in Year 1 for differing base carcass prices based upon a $10 C/S and feed cost of $300/$907.2 kg. For the model, CONV-LOW was considered as base. Treatments are defined as Natural (NAT) vs. Conventional (CONV) and 7% (LOW) and 12% (HIGH) dietary DM roughage inclusion level. Unless otherwise noted by a superscript, all parameters were significant $P \leq 0.05$.

**Table 7.10.** Estimated carcass value and net return of production systems in Year 2 with varying base carcass price[1]

| | Base Carcass Price ($/45.4kg) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $180 | | $190 | | $200 | | $210 | | $220 | |
| Item | Estimate | SE | Estimate | SE | Estimate | SE | Estimate | SE | Estimate | SE |
| Carcass value ($/cx) | | | | | | | | | | |
| Intercept | 1548.88 | 6.48 | 1634.79 | 6.73 | 1720.70 | 6.99 | 1806.61 | 7.26 | 1892.52 | 7.52 |
| NAT | (158.08) | 10.85 | (167.52) | 11.27 | (176.96) | 11.71 | (186.41) | 12.15 | (195.85) | 12.60 |
| CONV | - | - | - | - | - | - | - | - | - | - |
| Net return ($/steer) | | | | | | | | | | |
| Intercept[2] | (6.85) | 7.68 | 79.79 | 7.95 | 176.27 | 6.12 | 262.18 | 6.33 | 348.09 | 6.55 |
| NAT | (106.71) | 10.84 | (116.89) | 11.23 | (136.91) | 10.25 | (146.35) | 10.61 | (155.79) | 10.97 |
| CONV | 25.13 | 11.45 | 23.51 | 11.86 | - | - | - | - | - | - |

[1] Data in this table show the estimated carcass value and net return of production systems in Year 2 for differing base carcass prices based upon a $10 C/S and feed cost of $300/$907.2 kg. For the model, CONV-Z was considered as base. Treatments are defined as Natural (NAT) vs. Conventional (CONV) vs. Conventional w/ Zilmax (CONV-Z) All parameters were significant $P \leq 0.05$.

[2] Net return intercept P-values, were 0.37, <0.01, < 0.01, <0.01, and < 0.01.

**Table 7.11.** The Pearson correlation coefficients for parameters related to carcass value and net return[1]

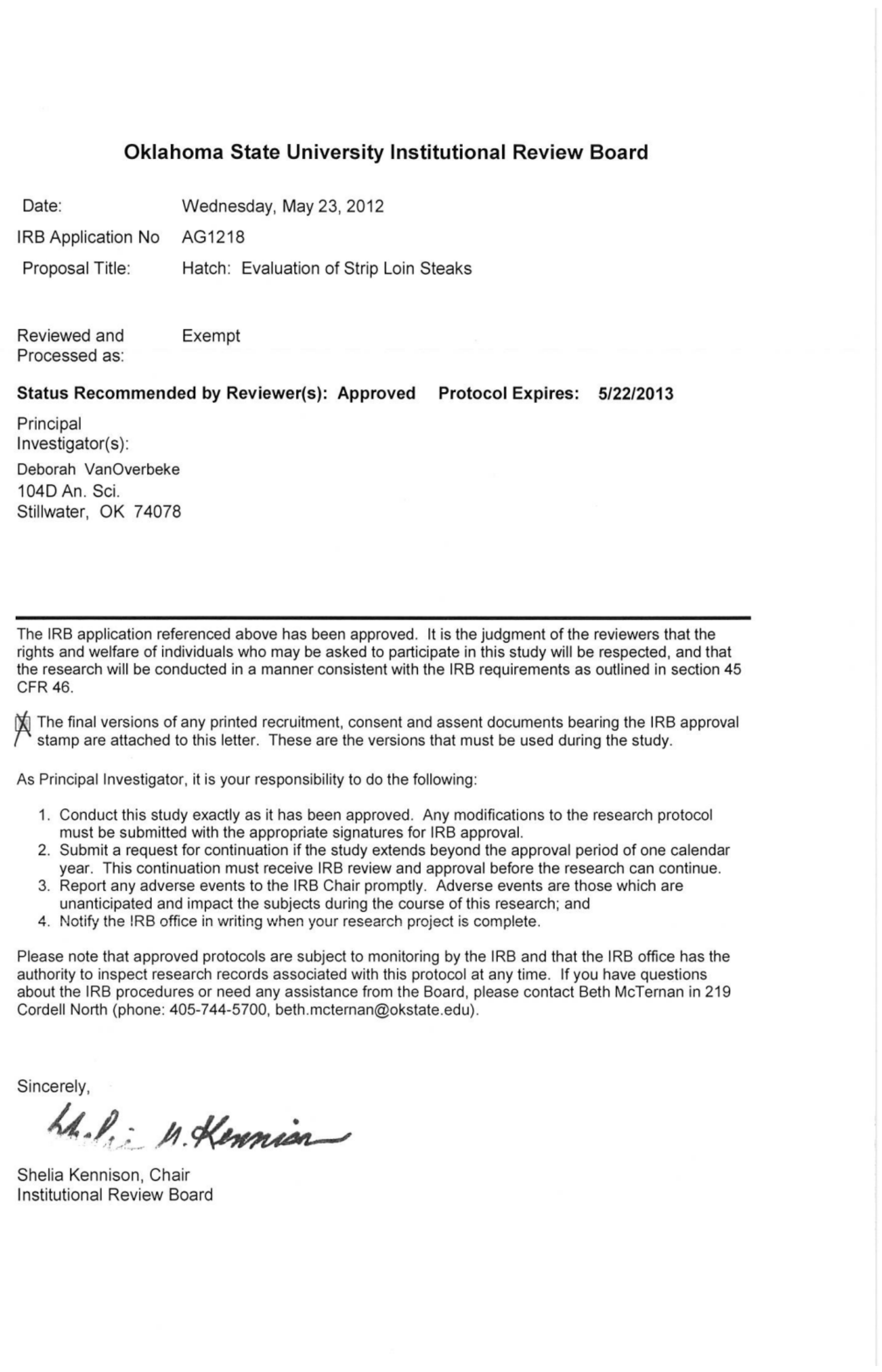
| | Variable | | | | | |
|---|---|---|---|---|---|---|
| Item | HCW | Marbling score | USDA YG | Longissimus area | 12th rib-fat thickness | ADG Feedlot |
| Carcass value, $/steer | 0.74 | 0.16 | -0.15 | 0.36 | -0.18 | 0.57 |
| Net return, $/steer | 0.46 | 0.21 | -0.21 | 0.20 | -0.33 | 0.44 |

[1] This table shows the Pearson correlation coefficients for parameters related to carcass value and net return. Data from both years were combined (n = 541 steers), base carcass value was $180.00 for Year 1 and $200.00 for Year 1I, feed price of $300/907.2 kg (DM, basis), and a $10 Choice/Select spread. All values were significant ($P < 0.01$).

# APPENDIX

All procedures involving live animals were approved by the Oklahoma State University Institutional Animal Care and Use Committee

Protocol # AG 12-2



## Oklahoma State University Institutional Review Board

| | |
|---|---|
| Date: | Wednesday, May 23, 2012 |
| IRB Application No | AG1218 |
| Proposal Title: | Hatch: Evaluation of Strip Loin Steaks |
| Reviewed and Processed as: | Exempt |

**Status Recommended by Reviewer(s): Approved Protocol Expires: 5/22/2013**

Principal Investigator(s):

Deborah VanOverbeke
104D An. Sci.
Stillwater, OK 74078

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The IRB application referenced above has been approved. It is the judgment of the reviewers that the rights and welfare of individuals who may be asked to participate in this study will be respected, and that the research will be conducted in a manner consistent with the IRB requirements as outlined in section 45 CFR 46.

☒ The final versions of any printed recruitment, consent and assent documents bearing the IRB approval stamp are attached to this letter. These are the versions that must be used during the study.

As Principal Investigator, it is your responsibility to do the following:

1. Conduct this study exactly as it has been approved. Any modifications to the research protocol must be submitted with the appropriate signatures for IRB approval.
2. Submit a request for continuation if the study extends beyond the approval period of one calendar year. This continuation must receive IRB review and approval before the research can continue.
3. Report any adverse events to the IRB Chair promptly. Adverse events are those which are unanticipated and impact the subjects during the course of this research; and
4. Notify the IRB office in writing when your research project is complete.

Please note that approved protocols are subject to monitoring by the IRB and that the IRB office has the authority to inspect research records associated with this protocol at any time. If you have questions about the IRB procedures or need any assistance from the Board, please contact Beth McTernan in 219 Cordell North (phone: 405-744-5700, beth.mcternan@okstate.edu).

Sincerely,

Shelia M. Kennison

Shelia Kennison, Chair
Institutional Review Board

# VITA

Casey Lee Maxwell

Candidate for the Degree of

Doctor of Philosophy

Thesis: ADVANTAGES OF TECHNOLOGY USE IN BEEF PRODUCTION SYSTEMS

Major Field: Animal Nutrition

Biographical:

Personal Data: Born in Amarillo, TX, on August 3, 1986, the son of Randy and Della Maxwell.

Education: Graduated from West Texas High School, Stinnett, Texas in May 2004; received Bachelor of Science in Animal Science with an emphasis in biotechnology in December 2007; received a Master of Science degree with a major in Animal Science at West Texas A&M University in December 2010; and completed the requirements for the Doctor of Philosophy degree in Animal Nutrition at Oklahoma State University in May 214.

Experience: Worked at Crutch Ranch, Borger Texas, 2000 to 2004; Willard Sparks Beef Research Center Herd Attendant 2004 to 2007; Graduate Assistant/Feed Mill Manager/Yard Manager at West Texas A&M Research Feedlot 2008 to 2010; Herd Manager Willard Sparks Beef Research Center Herd Manager 2011 to 2013.

Professional Memberships: American Society of Animal Science, American Registry of Professional Animal Scientists; American Meat Science Association