EFFECTS OF TECHNOLOGY USE IN BEEF PRODUCTION SYSTEMS ON MEAT QUALITY, CONSUMER PALATABILITY AND MUSCLE DIMENSIONS OF STRIP LOINS

By

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EFFECTS OF TECHNOLOGY USE IN BEEF

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DIMENSIONS OF STRIP LOINS

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Major Field: ANIMAL SCIENCE

Abstract: The objectives of this study were to examine the effect of beef production systems with and without the use of a beta-agonist on strip loin quality, consumer acceptance and muscle dimensions compared to an all-natural production system. The treatments include: all-natural (NAT), conventional (CONV), and conventional with zilpaterol hydrochloride (ZH; CONV-Z). Crossbred beef steers (n = 336) were randomized to one of three treatments and fed for an average of 136 d before slaughtered at Creekstone Farm, Arkansas City, KS. Forty-four carcasses that graded USDA Low Choice were identified for each treatment, loins were cut into 2.54-cm thick steaks, imaged, and aged for 14 or 21 d. Data were analyzed in the MIXED procedure of SAS and considered significant at $P < 0.05$. Analysis of Warner-Bratzler Shears (WBS) and slice shears (SS) showed CONV-Z steaks were tougher than CONV and NAT steaks regardless of aging. Outdoor consumer panelists found strip steaks from NAT and CONV-Z similar for tenderness, but less tender than CONV steaks ($P < 0.05$). No differences were found in juiciness, flavor and overall liking ($P > 0.10$). Trained panelists rated CONV-Z as less tender ($P < 0.05$) and less juicy ($P < 0.05$) than CONV or NAT steaks. Consumers were unable to detect tenderness or palatability differences found by WBS, SS and trained panelists. Conflicting consumer vs. trained panel results indicate consumers do not describe palatability differences in the same manner as trained panelists. Muscle dimension analysis indicated that *longissimus lumborum* (LL) area was increased in CONV-Z steers compared to CONV steers ($P < 0.01$) and CONV were increased compared to NAT steers ($P < 0.01$). *Gluteus medius* (GM) area was decreased in NAT steers compared to CONV-Z and CONV ($P < 0.01$). Maximum dorsal-ventral depth of LL at 25, 50 and 75% length of LL was increased in CONV-Z steers compared to CONV ($P < 0.01$) and NAT steers ($P < 0.01$), with the greatest increases at 25 and 75% depth. Results show improvement in muscle conformation creating a more usable center of the plate steak from the use of efficiency improving technologies.

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CHAPTER I

INTRODUCTION

Technology has become an important aspect in modern beef production as the world population increases and cattlemen are expected to produce more with the same, or fewer resources. The use and development of growth-promotants have had major impacts on cattlemen's ability to do just that. Beta-agonists, steroidal implants, ionophores and antibiotics have had a crucial role in helping cattle feeders to be profitable in the face of an ever-shrinking U.S. cattle inventory, fluctuating corn prices and high beef demand. In the later stages of feeding, when cattle start to deposit more fat than muscle, the use of growth-promoting technologies can help to increase muscle synthesis, ultimately increasing feed efficiency and pounds of lean beef produced.

Capper and Hayes (2012) found the use of growth-promotants have allowed producers to use 265,000 fewer hectares of land, 2.8 million fewer tons of feed and reduce manure output by 1.8 million tons. Despite the major sustainability benefits to using growth-promoting technologies, without the economic aspect they would not be where they are today. As a result of increased performance, beta-agonists and implants provide major economic returns in years where feed and cattle prices are high. Duckett and Pratt (2014) reported implanting cattle in 2013, a year where the average U.S. corn price approached $6.90/bu., yielded an average economic return of $102.62/head. Given the economic, performance and sustainability benefits of growth-promotants, it comes as no surprise that, today, around 45% of feedlot steers are fed a beta-agonist during the finishing phase (NAHMS, 2011). Usage of implants is even higher with approximately 97% of all feedlots steers having received at least one steroidal implant during the finishing stage (NAHMS, 2000).

While these technologies are important both economically and sustainably, and have helped to improve beef's overall price competitiveness compared to other proteins, there is some decline in palatability associated with the use of these technologies. Since tenderness, as well as juiciness and flavor, are major components of consumer eating satisfaction, it's important to understand the effect technology use may have in consumer palatability.

Therefore, the objective of the experiment presented is to evaluate the effects of different production systems and the production technologies each system utilized on meat quality, consumer palatability and muscle dimensions.

CHAPTER II

REVIEW OF LITERATURE

BETA-ADRENERGIC AGONISTS

Mode of Action

The use of beta-adrenergic agonists (**beta-agonists**) to improve animal performance and enhance carcass composition has been well documented since the early 1980s. However, much of the initial interest in beta-agonists was concentrated on developing human health applications treating asthma, muscular atrophy and obesity. The two beta-agonists federally approved for use in the U.S. are ractopamine hydrochloride (**Optaflexx or RH**, Elanco Animal Health, Greenfield, IN) and zilpaterol hydrochloride (**Zilmax or ZH**, Merck Animal Health, DeSoto, KS). Synthetic beta-agonists such as Optaflexx and Zilmax, are structurally similarly to the physiological catecholamines, norepinephrine and epinephrine (Mersmann, 1998).

Beta-adrenergic agonists bind to beta-adrenergic receptors (**βAR**) embedded in the plasma membrane of mammalian cells. Land et al. (1967) further classified β-receptors into the subtypes β_1, β_2, and β_3. Mersmann (1998) outlined the characterization of βAR subtype in different tissues as a means of better understanding the numerous physiological functions of beta-agonists. The primary subtype of concern in livestock production is the β2 receptor, the predominant subtype in skeletal muscle (Sillence and Matthews, 1994; Sillence et al., 2005). Schmidt et al. (1993) found that Optaflexx has been shown to bind solely with β_1, whereas Zilmax binds to both β_1 and β_2 receptors with greater affinity for β_2 receptors (Verhoeckx et al., 2005).

Numerous studies have documented the general effects of beta-agonists on both lipid and protein metabolism. The exact effects of beta-agonists on both are still debated and are species-dependent, but it is generally accepted beta-agonists work as repartitioning agents, redirecting nutrients away from adipose tissue and toward muscle (Moody et al., 2000). While most beta-agonists are generally thought to have a greater impact on protein degradation than protein synthesis, Bergen et al. (1989) showed Optaflexx works primarily by increasing protein synthesis with little effect on degradation, a result of its β_1 selectivity. Data have shown Zilmax both increases protein synthesis and slows degradation. Scramlin et al. (2010) postulated cattle supplemented with Zilmax exhibit greater fat metabolism activity, likely in non-carcass components such as the hide or viscera, compared to cattle supplemented with Optaflexx. However, in a review of Zilmax, Delmore et al. (2010) hypothesized feeding ZH actually mobilizes energy away from noncarcass components such as hide and viscera, shifting nutrients to carcass components.

Effects on Carcass Characteristics

It has been well documented feeding beta-agonists increases HCW and, as a result, dressing percentage (Avendaño-Reyes et al., 2006; Baxa et al., 2010; Boler et al., 2012; Scramlin et al. 2010). Increased HCW yields different effects on other carcass parameters impacted by changes in protein and fat metabolism accompanying beta-agonist supplementation. Generally, feeding Zilmax is associated with greater loin muscle area (**LMA)**, reduced kidney, pelvic, and heart fat (**KPH)**, and reduced 12th-rib fat depth with accordingly more desirable USDA Yield Grades. Given the increased carcass gain, a major component of grid marketing systems, it is recommended cattle supplemented are marketed on a carcass basis to increase returns (Maxwell, 2014). The impact of Optaflexx on LMA, 12th-rib fat depth and USDA Yield Grade is less pronounced than the response seen in Zilmax (Scramlin et al., 2010; Garmyn et al., 2014).

Zilmax is approved to feed for up to the last 40 d on feed at 7.5 PPM or 8.3 mg/kg (100% DM basis) with a 3 d withdrawal period (FDA, 2006). Baxa et al. (2010) examined the effects of Zilmax on performance and carcass parameters in a 30 d feeding trial where they discovered LMA was increased by 12.8% and 12th-rib fat depth decreased 10% compared to control steers. In contrast, Kellermeier et al. (2009) noted no difference in 12th-rib fat depth when steers were fed Zilmax for the same duration, although a treatment effect was still reflected in more desirable yield grades likely due to a 12.6% increase in LMA. Elam et al. (2009) studied the effect of Zilmax feeding duration on performance and carcass characteristics in beef steers finding larger LMA, less 12th-rib fat, and lower USDA yield grade in Zilmax treated than non-supplemented cattle. Marbling score, USDA yield grade, and 12th-rib fat decreased linearly with increased duration of Zilmax feeding (Elam et al., 2009). Although it has been shown effective to feed Zilmax up to 40 d, the manufacture recommendation for feeding is 20 d, allowing for maximal carcass gains while protecting marbling score and postmortem tenderness. Supporting this, Beckett et al. (2009) found no difference in marbling score between control calf-fed Holstein steers and those fed Zilmax for 20 d.

Optaflexx is approved to feed for up to the last 42 d at 70-400 mg/animal^{-1}/d^{-1} with no withdrawal period required (FDA, 2003). Boler et al. (2012) examined the effect of Optaflexx dosage on carcass characteristics of beef steers. A 4.9% increase in LMA was recorded and no differences in 12th-rib fat depth were recorded. No differences were found between dosages at 200 vs. 300 mg/animal^{-1}/d^{-1} (**RH 200 & RH 300**). In another study of the effects of Optaflexx on finishing heifers, Quinn et al. (2008) found no differences in LMA, 12th-rib fat depth, or average USDA yield grade in heifers supplemented with RH 200 for the last 28 d before slaughter compared to a control. As shown above, a majority of data suggest that feeding Optaflexx at a low dosage does not dramatically affect carcass characteristics. As previously mentioned, this is likely due to Optaflexx binding of β_1 receptors which make up a smaller percentage of total βAR.

Avendaño-Reyes et al. (2006) studied the effects of Optaflexx and Zilmax on finishing performance and carcass characteristics in a 33 d supplementation trial. Loin muscle area was increased and 12th-rib fat depth was decreased in cattle fed 60 mg of Zilmax daily compared to control steers, while no difference in LMA or 12th-rib fat depth was observed in cattle fed 300 mg Optaflexx compared to the control (Avendaño-Reyes et al., 2006). In another study, Scramlin et al. (2010) found increased LMA and decreased 12th-rib fat depth and USDA yield grade in beef steers fed Zilmax compared to Optaflexx.

Effects on Longissimus Muscle Dimensions

While it is commonly accepted that beta-agonists have a pronounced effect on increased LMA, there is less research discussing specific muscle conformation. In 2011, Lawrence et al. looked at longissimus lumborum (**LL**) muscle dimensions in calf-fed Holstein steers fed ZH compared to non-supplemented steers, finding a majority of increased LMA occurred through increased dorsal-ventral muscle depth (Lawrence et al., 2011). The study also found no change in gluteus medius area or the percentage of vein steaks (strip steaks with gluteus medius present) cut from each loin, all traits economically important to the steak-cutting industry (Lawrence et al., 2011).

Effects on Meat Quality and Consumer Palatability

Data have repeatedly shown tenderness to be the most important factor in beef palatability for consumer satisfaction (Miller et al., 2001; Savell et al., 1987). Baxa et al. (2010) showed Zilmax elicited a transition away from slower skeletal fiber types and increased faster more glycolytic fiber types, fitting with the assumption that skeletal muscle hypertrophy resulting from larger fiber diameters may play a direct role in the decreased tenderness associated with beta-agonist supplementation (Seideman and Theer, 1986). Given these findings, decreased tenderness is one of the biggest meat quality challenges associated with βAA supplementation.

Although tenderness differences may be a result of many factors, the factors most commonly discussed are antemortem dosage, compound strength, and postmortem aging. Boler et al. (2012) found no difference between Warner-Bratzler Shear (**WBS**) values for control and RH 200 at 7, 14 and 21 d aging. However, as dose increased so did WBS values as RH 300 steaks were significantly tougher than controls at all aging times (Boler et al., 2012). This low dosage response is further supported as Quinn et al. (2008) who showed no difference in WBS values between controls and RH 200 steaks aged for 14 d. In terms of compound strength, research has consistently showed Zilmax elicits a stronger response than Optaflexx, again, likely because Zilmax binds to β_2 receptors, the predominant subtype. Not surprisingly, there is generally a greater decrease in tenderness for cattle supplemented Zilmax than Optaflexx (Scramlin et al., 2010; Arp et al., 2014; Garmyn et al., 2014).

Postmortem aging has been proven an effective means of improving tenderness in steaks from cattle supplemented with beta-agonists. A number of studies have shown that increased aging has additive effects on tenderness. Scramlin et al. (2010) and Garmyn et al. (2014) showed tenderness of steaks from beta-agonist supplemented increased with increased aging duration. In fact with 21 d aging, steaks from Zilmax supplemented cattle approached levels from non-supplemented cattle (Scramlin et al., 2010). This is important information to retailers given most cuts take an average of 14 to 21 d to reach the point of consumer purchase (Brooks et al., 2000).

Given the importance of tenderness, instrumental measurements are utilized to objective measure differences; the two instrumental measures of tenderness are WBS and slice shear force (**SSF**). Although instrumental measurements clearly show differences between βAA supplementation and non-βAA, ultimately it is consumer perceptions that dictate the need, or lack thereof, for additional research. As a result, establishing consumer thresholds for tenderness became a major focus of fresh-meat quality research in the late 1990s. Miller et al. (2001) suggested tenderness classifications based on WBS values < 4.6 kg considered tender with 93% consumer acceptability. Ultimately, the American Society for Testing Materials (2011) adopted a threshold of 4.4 kg for certification of tender steaks. Arp et al. (2013) found the probability of failing to meet ASTM certified tender threshold for 14 d aged USDA Low Choice steaks to be statistically lower for steers fed RH 200 or RH 300 than steers fed RH 400 or ZH, 0.04 ±0.03 and 0.19 ± 0.05, respectively. On the other hand, Garmyn et al. (2010) found that although Zilmax reduced tenderness numerically, WBS values were within consumer acceptability thresholds (WBSF < 4.6 kg). Hilton et al. (2009) demonstrated the same finding with increased WBS values with increased Zilmax supplementation; however, no difference in consumer acceptability was found between control and ZH steaks when aged for 14 d, reflecting the importance of utilizing postmortem aging to protect consumer acceptability in beta-agonist supplementation.

In comparing juiciness between trained and consumer panels, Hilton et al. (2009) found steaks rated by trained panelists to be less juicy compared to controls, while consumers were unable to recognize a difference. In another study, no observable differences in juiciness from βAA supplementation were observed in trained or consumer panels (Mehaffey et al., 2009). Kellermeier et al. (2009) observed feeding Zilmax increased the percentage of purge loss compared to controls. Arp et al. (2013) postulated this might be responsible for decreased juiciness observed in sensory panels. However, Garmyn et al. (2010) in examining the effects of Zilmax on thawing loss, found no difference in percent loss.

Neely et al. (1998) found flavor was as important as tenderness in determining overall liking in beef consumer panels. Correspondingly, this study also showed the degree of intramuscular fat to be directly related to the flavor component of beef palatability (Neely et al., 1998). Trained panelists in several other studies observed no differences in flavor attributes (Arp et al., 2012; Garmyn et al., 2010).

GROWTH PROMOTING IMPLANTS

Mode of Action

There are three primary classes of growth-promoting steroids: estrogens, androgens, and progestins. Johnson et al. (2013) summarized that of the three classes, steroids can be naturally occurring (estrogen, testosterone and progesterone) or synthetically derived (zeranol, trenbolone acetate and melengestrol acetate). There are currently 33 FDA approved implants (Duckett and Pratt, 2014.)

Steroids increase protein accretion by binding to cytosolic receptors (Bryant et al., 2010) that increase production of insulin-like growth factor I (IGF-1) and growth hormone (GH; Johnson et al., 2013). Increased IGF-1 and GH concentrations activate satellite cell proliferation and provide the DNA needed for muscle cells to increase in size (Johnson et al., 1998). Studies have proven satellite cells play an important role in postnatal muscle growth with up to 80 percent of muscle DNA originating from satellite cell division (Therkildsen and Oksbjerg, 2009).

Although all growth-promotants are similar in their ability to increase production, improve feed efficiency and have been proven to have additive effects when used in combination (Baxa et al., 2010), Bryant et al. (2010) found steroidal implants and beta-agonists elicit different metabolic responses as measured by classical indicators of fat and muscle catabolism and anabolism.

Implant Strategy

The number of different implants available is both a result and cause of implant strategy research designed to ensure maximum effectiveness. While many implants may be similar, each has slightly different characteristics. The most important characteristic to take into account may be potency (or "aggressiveness" as commonly referred to in the industry). While active hormone and dosage are the most obvious determinants of implant aggressiveness, the implants carrier compound can have an impact as well. Implant strategies are designed to maximize benefits of exposer while reducing negative impacts and most commonly focus on finish date, price spread, genetic potential for marbling, nutritional plane and feeding programs (Holt, 2009).

Effect on Carcass Characteristics

Given the amount of literature over the effects of steroidal implant usage on carcass characteristics and live performance, the ability of implants to increase HCW and LMA is commonly accepted. As summarized by Duckett and Pratt (2014), implants can increase HCW by 6 to 8% and LMA by up to 9%. Where this study is more interesting is comparing results in carcass characteristics to live performance results. Where live performance gains were proven significant for a single estrogenic implant, they were not for HCW or LMA, suggesting increases in muscle mass require a more aggressive implant (Duckett and Pratt, 2014). Where there is a potent effect on muscle mass, most data suggest little to no change in subcutaneous fat thickness (Duckett and Pratt, 2014).

Reduction of marbling in the longissimus muscle is a well-recognized effect of implant usage that is believed to be caused by a dilution effect associated with increased muscle mass (Bryant et al., 2010). On average, the use of implants decrease marbling scores by 4 to 11%, a surprisingly large range (Duckett and Pratt, 2014). In extremes, Platter et al. (2003) demonstrated a 91-point reduction in marbling score of carcasses from cattle implanted five times when compared to nonimplanted steers, although five implants is clearly above the industry average. Foutz et al. (1997) found the effects of time of implantation had no effect on marbling score regardless of type of implant or reimplantation. While more recent studies have shown otherwise, these results may possibly be explained by the date chosen for reimplantation, which in this study is well before the recognized period of maximum marbling deposition (i.e., d 84 to 112 on feed during finishing; Duckett and Pratt, 2014). Johnson et al. (1996) showed no change in marbling whether slaughtered 40, 115, or 143 days post implanting.

Effects on Meat Quality and Consumer Palatability

Decreased WBS values are associated with implant usage as well, and is most likely caused by increased muscle diameter observed through hypertrophy. Similar to other traits, the effects of implants are generally additive in nature. Scheffler et al. (2003)

provided more evidence for the additive effects of implants by finding a linear increase in WBS with number of implants administered.

Platter et al. (2003) showed consumers found steaks from implanted steers to be tougher than those from their nonimplanted counterparts. These findings fit with WBS values found in this and other studies. More interesting was the study's finding that consumers were unable to tell a difference in tenderness between steaks from steers implanted with anywhere from two to five implants over the course of the animal's lifetime (Platter et al., 2003). Warner-Bratzler Shear values reflect similar findings and appear to show a plateau in additive effects on tenderness.

Again, flavor and juiciness are other traits of consumer importance. Consumers found steaks from implanted cattle to be less flavorful and juicy than nonimplanted controls (Platter et al., 2003). Again, consumers were unable to distinguish differences between steaks from cattle implanted two to five times (Platter et al., 2003).

Another concern regarding estrogenic implants is potential impacts on skeletal maturity. Hyperestrogenism, or the acceleration of skeletal maturation caused by the additive effects of multiple estrogen sources, can result in cattle, age 14 to 30 months, being misclassified as B maturity and ultimately receiving carcass discounts anywhere from $20 - $50/cwt. (Acheson and Tatum, 2014). While several studies (Turner et al., 1981; Foutz et al., 1997) have shown exogenous estrogen sources negatively impact skeletal maturity, in partial contrast Platter et al. (2003) found no differences in skeletal maturity until cattle were implanted either four or five times.

ANTIBIOTICS AND IONOPHORES

Mode of Action

Tylosin (Tylan, Elanco Animal Health, Greenfield, IN) is the primary feed-grade antibiotic used to reduce the incidence of liver abscesses. By preventing and reducing the presence of *Fusobacterium necrophorum* and *Actinomyces pyogenes* bacteria in the rumen, tylosin reduces abscess incidence by 40 to 70% (Nagaraja and Chengappa, 1998). Tylosin, a macrolide, works primarily on Gram-positive bacteria. Although *F.* necrophorum is a Gram-negative, tylosin has been shown to have an inhibitory effect on the bacteria (Nagaraja and Chengappa, 1998). Severe liver abscesses can result in reduced animal performance and ultimately decrease carcass yields due to decreased dressing percentage and excessive carcass trim because of abscess adhesions.

Monensin (Rumensin, Elanco Animal Health, Greenfield, IN), an orally fed ionophore, is used to inhibit Gram-positive bacteria, thereby increase feed efficiency and reduce digestive disorders (Duffield et al., 2012). The mode of action is through altered volatile fatty acid (**VFA**) ratios in the rumen. Shifting VFA production toward propionate and away from butyrate and acetate, monensin allows for more energy to be released from feeds through increased glucose (Ellis et al., 2012).

Effects on Carcass Characteristics and Meat Quality

In evaluating the effects of feeding ZH with monensin and tylosin on feedlot performance and carcass characteristics, Montgomery et al. (2009) found the use of monensin and tylosin had no effect on HCW, 12th-rib fat thickness, KPH or marbling score. The study also showed monensin and tylosin did have some effect on LMA, as well as some interaction between ZH and monensin and tylosin, on LMA and USDA yield grade (Montgomery et al., 2009). As an extension of this project, Hilton et al. (2009) examined the effects on meat quality and consumer palatability. Withdrawal of monensin and tylosin decreased juiciness scores in consumer sensory panels, although no other yield or palatability traits were affected. Interestingly, trained panelists were not able to confirm the difference in juiciness found by consumers (Hilton et al., 2009). Additionally, no interactions between Zilmax, monensin and tylosin were observed (Hilton et al., 2009).

CONCLUSIONS

Growth-promoting technologies are a proven method for increasing carcass yields and, ultimately, saleable product all while reducing resource inputs. The overall trend in the literature suggests some decrease in tenderness is associated with these technologies, but methods for using technology and management practices can also have a large role mitigating palatability differences. Data are lacking in analyzing the use of multiple technologies in beef production systems with regard to the effects on meat quality. The experiments presented in this thesis aim to address questions about consumer vs. trained panelists sensory findings in regard to different production systems.

CHAPTER III

EFFECTS OF TECHNOLOGY USE IN BEEF PRODUCTION SYSTEMS ON MEAT QUALITY AND CONSUMER PALATABILITY

ABSTRACT

The objectives of this study were to examine the effect of beef production systems with and without the use of a beta-agonist on strip loin quality and consumer acceptance compared to an all-natural production system. The treatments include: all-natural (NAT), conventional (CONV), and conventional with zilpaterol hydrochloride (ZH; CONV-Z). Crossbred beef steers (n = 336) were randomized to one of three treatments and fed for an average of 136 d before slaughtered at Creekstone Farm; Arkansas City, KS. Forty-four carcasses that graded USDA Low Choice were identified for each treatment, loins were cut into 2.54-cm thick steaks and aged for 14- and 21 d. Both shear and panel data were analyzed in the MIXED procedure of SAS and considered significant at $P < 0.05$. Analysis of Warner-Bratzler Shears (WBS) showed at 14 d aged both NAT and CONV steaks had lower shear values compared to CONV-Z. At 21 d, WBS were different with NAT steaks having the lowest value and CONV-Z the highest ($P < 0.01$). Slice shear

(SS) values from steaks aged 14 d, were different with NAT having the lowest SS and CONV-Z, the highest ($P < 0.01$). Of steaks aged 21 d, average SS of NAT and CONV steaks were lower compared to CONV-Z ($P < 0.01$). Outdoor consumer panelists found strip steaks from NAT and CONV-Z similar for tenderness, but less tender than CONV steaks ($P < 0.05$). No differences were found in juiciness, flavor and overall liking ($P > 0.10$). Trained panelists ranked NAT and CONV steaks similar for juiciness and tenderness ($P > 0.10$) at 14 d aged with CONV-Z rated less juicy ($P < 0.05$) and less tender ($P < 0.05$) compared to NAT and CONV. By 21 d aged, NAT were ranked as more tender ($P < 0.05$) and more juicy ($P < 0.05$) compared to CONV, but both were rated higher ($P < 0.05$) than CONV-Z steaks. Consumers were unable to detect tenderness or palatability differences found by WBS, SS and trained panelists.

INTRODUCTION

Technology has become an important aspect in modern beef production as the world population increases and cattlemen are expected to produce more with the same, or fewer resources. The use and development of growth-promotants have had major impacts on cattlemen's ability to do just that. Beta-agonists, steroidal implants, ionophores and antibiotics have had a crucial role in helping cattle feeders to be profitable in the face of an ever-shrinking U.S. cattle inventory, fluctuating corn prices and high beef demand. In the later stages of feeding, when cattle start to deposit more fat than muscle, the use of growth-promoting technologies can help to increase muscle synthesis, ultimately increasing feed efficiency and pounds of lean beef produced.

Capper and Hayes (2012) found the use of growth-promotants have allowed producers to use 265,000 fewer hectares of land, 2.8 million fewer tons of feed and reduce manure output by 1.8 million tons. Despite the major sustainability benefits to using growth-promoting technologies, without the economic aspect they would not be where they are today. As a result of increased performance, beta-agonists and implants provide major economic returns in years where feed and cattle prices are high. Duckett and Pratt (2014) reported implanting cattle in 2013, a year where the average U.S. corn price approached $6.90/bu., yielded an average economic return of $102.62/head. Given the economic, performance and sustainability benefits of growth-promotants, it comes as no surprise that, today, around 45% of feedlot steers are fed a beta-agonist during the finishing phase (NAHMS, 2011). Usage of implants is even higher with approximately 97% of all feedlots steers having received at least one steroidal implant during the finishing stage (NAHMS, 2000).

While these technologies are important both economically and sustainably, and have helped to improve beef's overall price competitiveness compared to other proteins, there is some decline in palatability associated with the use of these technologies. Since tenderness, as well as juiciness and flavor, are major components of consumer eating satisfaction, it's important to understand the effect technology use may have in consumer palatability.

Therefore, the objective of the experiment presented is to evaluate the effects of different production systems and the production technologies each system utilized on meat quality and consumer palatability.

METHODOLOGY

Cattle Management and Study Treatments

Animals were handled in a manner consistent with institutional regulations and standards set forth by the Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching (FASS, 1999).

A feedlot experiment was conducted by Maxwell (2014) to study the effects of production technologies on feedlot performance and carcass characteristics using crossbred beef steers (n = 336) blocked by body weight and randomized to one of three treatments. Treatments consisted of an all-natural treatment (**NAT**), a conventional treatment (**CONV**) and conventional treatment with the inclusion of ZH (**CONV-Z**). The NAT cattle received no antibiotics or growth-promoting technologies, qualifying for the Creekstone Farm Natural Black Angus Beef brand and premiums. If NAT cattle were found to require antibiotics they were treated and removed from trial. Both the CONV and CONV-Z were fed 33 and 9 mg/kg of monensin and tylosin (Rumensin and Tylan, Elanco Animal Health) daily, respectively. Both were implanted on d 0 with 40 mg estradiol and 200 mg trenbolone acetate (Revalor-XS, Merck Animal Health). The CONV-Z steers also received 6.76 mg/kg of zilpaterol hydrochloride (Zilmax, Merck

Animal Health) for 20 d before slaughter with a 3-4 d withdraw. Cattle were fed the same base concentrate diet for an average of 136 d as shown in Tables 1 & 2.

Slaughter

On d 84, steers were separated into slaughter groups based on a visual appraisal of 12th rib fat thickness and projected slaughter weight. Cattle were slaughtered at Creekstone Farms, Arkansas City, KS on September 12 and 13, 2013. The CONV and CONV-Z cattle were slaughtered on Thursday while NAT cattle were slaughtered on Friday due to requirements of the packing facility.

Strip Loin Selection and Preparation

Strip loins (n = 132) were transported from Creekstone Farms to Oklahoma State University and were fabricated into 2.54-cm thick steaks using a gravity slicer (model SE-12, Bizerba USA, Inc., Sandston, VA). Starting on the anterior end, steaks were numbered and the anterior face of each was pictured for muscle dimension measurements before individually packaged and aged for either 14- or 21 d. In each analysis, the same steak number from each loin was used to reduce anterior-posterior variation.

Instrumental Tenderness Analysis

Two steaks from each of the 44 loins represented in each treatment were designated for Warner-Bratzler shear force (**WBS**) and slice shear force (**SSF.)** Steaks were tempered for approximately 24 h at 4°C and cooked on an XLT Impingement Oven (model 3240-TS, BOFI Inc., Wichita, KS) at 200°C to an internal temperature of 71°C. After cooking, the WBS steaks were placed on covered trays to cool at 4°C for 18 h. Six cores were removed from each steak parallel to the muscle fiber and visual degree of doneness was recorded before sheared perpendicular to the muscle fiber. One slice was removed from each of the SSF steaks while still hot. Shear force was determined using an Instron Universal Testing Machine (model 4502, Instron Corporation, Norwood, MA.) Operating a crosshead speed of 200 mm/min for WBS and 500 mm/min for SSF, maximum load (kg) was recorded for each core or slice. Mean maximum load was calculated for the 6 WBS cores.

Consumer Sensory Analysis

The consumer taste panel was conducted prior to an OSU home football game on November 23, 2013. Consumer panel steaks were aged 21 d. A total of 400 consumers were served outside prior to the game and, given daylight constraints, an additional 100 consumers were served the following Monday, November 25, 2013. Twenty-seven steaks were chosen for each group of 100 consumers based on similar mean WBS to reduce treatment variation served to panelists. Steaks were tempered for approximately 24 h at 4°C and cooked on an XLT Impingement Oven (model 3240-TS, BOFI Inc., Wichita, KS) at 200°C to an internal temperature of 71°C. Steaks were cut into 1-cm^3 pieces and put in color coded cups based on treatment. Colors were unknown to both servers and panelists and were changed for each group of 100 consumers to prevent bias. Consumers were asked to evaluate steak samples using a 9-point hedonic scale for tenderness, juiciness, flavor and overall liking. Each consumer filled out a demographic form that included the following information: marital status, sex, age, ethnicity, employment status, household income, household size, and beef consumption (Table 3).

Trained Sensory Panel

Trained taste panelists were selected based on performance during training. Eight panelists were seated for each session and evaluated no more than 12 samples per session. Steaks were tempered for approximately 24 h at 4°C and cooked on the impingement oven at 200°C to an internal temperature of 71°C. Steaks were cut into 1-cm^3 pieces, 3 cubes were included in each sample cup, assigned a number at random and placed in warmers with hot packs to maintain temperature through sensory evaluation. Samples were evaluated under red lighting and panelists were provided deionized water and crackers as a palette cleanser in-between samples. Panelists were asked to evaluate initial and sustained juiciness (8=extremely juicy, 1=extremely dry), first impression and overall tenderness (8=extremely tender, 1=extremely tough), connective tissue (8=no connective tissue, 1=abundant connective tissue), as well as beef, beef fat, metallic and oxidative flavors (1=no presence, 8=strong presence).

Statistical Analysis

Least square means (LSmeans) and standard errors (SE) were generated using the MIXED Procedure of SAS (SAS 9.3; SAS Inst. Cary, NC). Individual animal was used as the experimental unit and strip loins served as the sampling unit. For instrumental tenderness, strip loin number was used as a random effect. Degree of doneness was found to be significant and, therefore, used as a covariate to reduce variation within WBS and SS. In trained panel analysis, strip loin number and panelist were used as random effects. Both instrumental tenderness and trained taste panel data were grouped by days aged since aging period was not analyzed but is known to have an effect on tenderness. For the consumer panel, serving group and panelist were used as random effects. Location (outdoor vs. indoor) was found to be significant so analyses were grouped accordingly (outdoor vs. indoor). For all analyses, when a significant F-test was identified ($P < 0.05$), LS means were separated using a pairwise t-test. Means were considered significantly different at ($P < 0.05$) and trends were evaluated at $0.05 < P < 0.10$.

RESULTS AND DISCUSSION

Instrumental Tenderness

Warner-Bratzler shear force of 14 d aged steaks increased 0.68 kg for CONV-Z steaks compared to CONV steaks (4.28 ± 0.10 vs. 3.60 ± 0.10 kg; $P < 0.0001$) and 0.41 kg for CONV steaks compared to NAT steaks (3.60 ± 0.10 vs. 3.20 ± 0.10 kg; $P = 0.0053$), indicating a difference in all three treatments. Similarly, SSF increased 6.44 kg for CONV-Z steaks compared to CONV steaks (27.06 ± 0.85 vs. 20.62 ± 0.83 kg; $P < 0.0001$) and 3.98 kg for CONV steaks compared to NAT steaks (20.62 ± 0.83 vs. 16.64 ± 0.83 kg; $P = 0.0010$). Similar to differences seen between CONV and NAT steaks, Garmyn et al. (2011) also found 14 d aged steaks from cattle receiving a Revalor-S or Revalor-XS implant had increased WBS compared to a non-implanted control. In contrast, Garmyn et al. (2011) did not find significant implanting differences in SSF at 14 d aged.

At 21 d of age, there was again a difference in WBS between all three treatments. Warner-Bratzler shear increased 0.57 kg for CONV-Z steaks compared to CONV (4.22 ±

0.11 vs. 3.65 ± 0.11 kg; $P = 0.0002$) and 0.53 kg for CONV steaks compared to NAT steaks (3.65 ± 0.11 vs. 3.11 ± 0.11 kg; $P = 0.0005$). Interestingly, the SSF findings were different than WBS findings for 21 d aged steaks. No difference was detected ($P = 0.1086$) in SSF values of NAT and CONV steaks, but data showed a 4.19 and 5.46 kg increase for CONV-Z steaks compared to CONV and NAT steaks, respectively (20.95 ± 0.56 vs. 16.76 ± 0.55 & 15.49 ± 0.56 kg; $P < 0.0001$).

Additive effects of aging on tenderness are shown in the SSF findings reflect findings in several other studies (Hilton et al., 2009; Garmyn et al., 2014). In this study, SSF reflected a greater percent change in WBS when aged for longer periods. While the use of ZH increased SSF of CONV-Z steaks by 62.62% at 14 d aged, by 21 d aged that percentage dropped dramatically, with the use of ZH increased SSF by 35.25% compared with NAT steaks. There was no additive effect of aging shown in WBS as the use of ZH increased SSF of 14 d aged steaks by 33.75% and 21 d aged steaks by 35.69% compared with NAT steaks, results similar to those found by Kellermeier et al. (2009).

Hilton et al. (2009) demonstrated monensin and tylosin had no impact on WBS, therefore, tenderness differences between CONV and NAT steaks are likely due to implant usage. The data from this study are similar to past results showing increased toughness associated with steroidal implants (Platter et al., 2003; Scheffler et al., 2003).

The data from this study also show that feeding ZH increased WBS and SSF in strip steaks aged both 14- and 21 d compared with steaks from cattle not fed ZH. These results agree with past research, which has reported increased toughness in steaks from cattle fed ZH compared to a non-ZH control (Kellermeier et al., 2009; Mehaffey et al., 2009; Garmyn et al., 2011; Arp et al., 2014).

Consumer Sensory Analysis

Since consumers rated samples both indoor and outdoor, an initial analysis was conducted to determine if the sampling location had a difference on consumer ratings. There were differences ($P < 0.0010$) in location for consumer ratings of juiciness, flavor and overall liking. Tenderness ratings were not different ($P = 0.0809$) for indoor vs. outdoor consumers, but since there was a trend for different ratings all palatability attributes were analyzed within location. Strikingly different results found by indoor vs. outdoor consumers may have been caused by level of discrimination, likely caused by environmental and demographic differences.

The outdoor data (Table 3) showed a difference ($P = 0.0050$) in tenderness between CONV steaks compared to CONV-Z and NAT steaks, indicating consumers found CONV steaks to be the most tender and could not tell a difference ($P = 0.6655$) in tenderness between CONV-Z and NAT steaks. There was a trend ($P = 0.0772$) for steaks from CONV cattle to have more desirable juiciness than steaks from NAT cattle. No differences ($P = 0.1933$ and $P = 0.1283$) were found in flavor or overall liking between NAT, CONV, and CONV-Z steaks; however, consumers rated NAT and CONV-Z steaks more similar, numerically, than CONV steaks. These results agree with past research showing at 21 d aging, consumers were unable to tell differences between steaks from cattle fed ZH and a control in juiciness (Mehaffey et al., 2009), flavor (Mehaffey et al., 2009; Garmyn et al., 2014) and overall liking (Garmyn et al., 2014). Interestingly, in this study trained panelists' ratings of oxidative flavors mirror numerical differences shown in consumer ratings, with NAT and CONV-Z steaks rated similar compared to CONV steaks.

The indoor results (Table 4) showed a difference in tenderness, juiciness, flavor and overall liking between CONV-Z steaks compared to NAT and CONV steaks (P = 0.0001, P = 0.0005, P = 0.0222 and P = 0.0014, respectively), indicating CONV-Z steaks were less tender, juicy, flavorful and overall less desirable than NAT and CONV steaks.

Trained Sensory Analysis

All trained panel sensory findings are detailed in Tables 5 and 6.Trained sensory panelists found 14 d aged CONV-Z steaks to be have less initial and sustained juiciness than CONV and NAT steaks (P = 0.0002). By 21 d of age, panelists found differences ($P < 0.0001$) between all three treatments in initial and sustained juiciness. Panelists rated NAT steaks as more juicy than CONV steaks (P = 0.0002) and CONV steaks rated more juicy than CONV-Z steaks as well (P = 0.0426). Sustained juiciness ratings were similar to initial juiciness findings. A difference ($P < 0.0001$) between all three treatments indicating panelists rated sustained juiciness of NAT steaks as more juicy than CONV steaks and CONV steaks were rated juicier than CONV-Z.

Tenderness results mirrored sensory findings for juiciness for both aging periods. At 14 d aging, panelists rated CONV-Z steaks tougher on initial and overall tenderness ($P < 0.0001$) than CONV and NAT steaks. By 21 d aging, all three treatments were rated differently ($P < 0.0001$) on initial and overall tenderness with NAT steaks rated as the most tender, CONV steaks intermediary and CONV-Z steaks rated as the least tender.

Also similar to this study, Hilton et al. (2009) found trained panelists were able to determine steaks from cattle fed ZH were less juicy and tender. Even at 28 d aging, Leheska et al. (2009) showed trained panelists found steaks from cattle fed ZH were less tender.

Connective tissue was different ($P < 0.0001$) between all three treatments when aged 14 d with NAT steaks having the least connective tissue, CONV steaks intermediary, and CONV-Z steaks having the most connective tissue. With 21 d aging, connective tissue differences seen between NAT and CONV steaks were no longer significant ($P = 0.6185$). However, panelists still rated NAT and CONV steaks as having less connective tissue than CONV-Z steaks ($P = 0.0040$).

Trained panelists found no difference ($P = 0.1908$) in beef flavor at 14 d aged, but by 21 d aging, NAT steaks were rated as having stronger beef flavor than CONV-Z steaks ($P = 0.0183$). The data showed a difference ($P = 0.0033$ & $P = 0.0271$) between treatments for beef fat flavor at both 14 and 21 d aging, respectively. At 14 d aging, panelists rated NAT steaks as having more beef-fat flavor than CONV and CONV-Z steaks ($P = 0.0353$). By 21 d aging, panelists no longer found a difference ($P = 0.1222$) between NAT and CONV steaks, but NAT steaks were still rated higher in beef-fat flavor than CONV-Z steaks ($P = 0.0072$). Trained panelists in Arp et al. (2014) who sampled 14 d aged strip steaks were unable to find differences in beef flavor or beef-fat flavor. Interestingly, CONV steaks had less oxidative flavor compared to CONV-Z and NAT steaks ($P = 0.0406$). With 21 d aging, there were no differences ($P = 0.4026$) in oxidative flavor between any of the treatments. No differences in metallic flavor were found between any treatment at 14- or 21 d aging.

IMPLICATIONS

The conflicting consumer vs. trained panel results indicate consumers do not describe palatability differences in the same manner as trained panelists. Although only numerically, consumers rated 21 d aged steaks from cattle supplemented with ZH similar to steaks from all-natural cattle; statistically, consumers rated NAT, CONV, CONV-Z as the same in juiciness, flavor, and overall liking. Ultimately, this study demonstrates ZH and other growth promoting technologies are of benefit to beef production systems since consumers find the quality of strip steaks to be acceptable.

Table 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 2. Analyzed nutrient composition of diets fed

	Experimental diet[1]		
Ingredient[2]	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 d withdrawal.

Table 3. Demographic characteristics from consumers participating consumer evaluation outdoor

Characteristic	Response	% of Consumers
Marital Status	Single	53.2
	Married	46.8
Sex	Male	62.1
	Female	37.9
Employment	Full-time	58.0
	Part-time	8.9
	Not Employed	10.9
	Student	22.2
Ethnicity	Caucasian	82.6
	Hispanic	3.6
	African	1.5
	Asian	1.5
	Indian	8.4
	Other	2.4
Age, yr.	18-25	37.7
	26-35	16.6
	36-45	17.2
	46-55	17.5
	56-65	8.4
	66+	2.7
Household income level	Less than $20,000	21.5
	$20,000 to $39,999	8.5
	$40,000 to $59,999	14.5
	$60,000 to $79,999	12.6
	$80,000 to $99,999	12.6
	Greater than $99,999	30.3
Household size	1	14.5
	2	30.1
	3	15.9
	4	24.6
	5 or more	14.8
Beef consumption	Greater than 3 times per week	56.8
	1 to 2 times per week	32.8
	2 to 3 times per month	6.7
	Once per month	2.9
	Less than once per month	0.9

Table 4. Demographic characteristics from consumers participating consumer evaluation indoor

Characteristic	Response	% of Consumers
Marital Status	Single	28.1
	Married	71.9
Sex	Male	42.5
	Female	57.5
Employment	Full-time	33.0
	Part-time	12.5
	Not Employed	3.4
	Student	50.0
Ethnicity	Caucasian	91.7
	Hispanic	2.4
	African	2.4
	Asian	0.0
	Indian	2.4
	Other	1.2
Age, yr.	18-25	65.2
	26-35	12.4
	36-45	9.0
	46-55	6.7
	56-65	4.5
	66+	2.2
Household income level	Less than $20,000	33.7
	$20,000 to $39,999	19.8
	$40,000 to $59,999	16.3
	$60,000 to $79,999	12.8
	$80,000 to $99,999	7.0
	Greater than $99,999	10.5
Household size	1	25.8
	2	30.3
	3	15.7
	4	14.6
	5 or more	13.5
Beef consumption	Greater than 3 times per week	64.0
	1 to 2 times per week	28.1
	2 to 3 times per month	6.7
	Once per month	1.1
	Less than once per month	0.0

Table 5. Effects of treatment on trained taste panel attributes and shear force values of 14 d aged strip steaks

	Treatment[1]				
Item	NAT	CONV	CONV-Z	*P-value*	SEM
Initial juiciness[2]	6.26[a]	6.24[a]	5.97[b]	<0.01	0.09
Sustained juiciness[2]	6.07[a]	6.01[a]	5.69[b]	<0.01	0.06
Initial tenderness[3]	6.72[a]	6.58[a]	5.88[b]	<0.01	0.10
Overall tenderness[3]	7.06[a]	6.93[a]	6.22[b]	<0.01	0.11
Connective tissue[4]	7.61[a]	7.48[b]	7.12[c]	<0.01	0.06
Beef flavor[5]	5.26	5.23	5.08	0.19	0.07
Beef-fat flavor[5]	2.86[a]	2.61[b]	2.46[b]	<0.01	0.14
Metallic flavor[5]	3.07	3.24	3.28	0.36	0.17
Oxidative flavor[5]	1.57[a]	1.35[b]	1.51[a]	0.04	0.11
Warner-Bratzler Shear, kg	3.20[a]	3.61[b]	4.28[c]	<0.01	0.10
Slice shear, kg	16.64[a]	20.62[b]	27.06[c]	<0.01	0.83

[a,b,c] LS means within a row without 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] 1 = extremely dry; 2 = very dry; 3 = moderately dry; 4 = slightly dry; 5 = slightly juicy; 6 = moderately juicy; 7 = very juicy; 8 = extremely juicy

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

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

[5] 1 = no presence; 8 = very strong presence

Table 6. Effects of treatment on trained taste panel attributes and shear force values of 21 d aged strip steaks

	Treatment[1]				
Item	NAT	CONV	CONV-Z	*P-value*	SEM
Initial juiciness[2]	6.34[a]	6.09[b]	5.94[c]	<0.01	0.05
Sustained juiciness[2]	6.17[a]	5.92[b]	5.77[c]	<0.01	0.07
Initial tenderness[3]	6.79[a]	6.53[b]	6.15[c]	<0.01	0.10
Overall tenderness[3]	6.95[a]	6.64[b]	6.31[c]	<0.01	0.08
Connective tissue[4]	7.47[a]	7.43[a]	7.24[b]	<0.01	0.09
Beef flavor[5]	5.47[a]	5.39[ab]	5.26[b]	0.05	0.09
Beef-fat flavor[5]	3.24[a]	3.09[ab]	2.99[b]	0.03	0.10
Metallic flavor[5]	3.43	3.51	3.60	0.28	0.12
Oxidative flavor[5]	1.32	1.23	1.36	0.40	0.12
Warner-Bratzler Shear, kg	3.11[a]	3.65[b]	4.22[c]	<0.01	0.11
Slice shear, kg	15.49[a]	16.76[a]	20.95[b]	<0.01	0.56

[a,b,c] LS means within a row without 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] 1 = extremely dry; 2 = very dry; 3 = moderately dry; 4 = slightly dry; 5 = slightly juicy; 6 = moderately juicy; 7 = very juicy; 8 = extremely juicy

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

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

[5] 1 = no presence; 8 = very strong presence

Table 7. Effects of treatment[1] on consumer taste panel attributes from 21 d aged strip steaks

	Outdoor (n = 400)				Indoor (n = 100)			
Attribute	NAT	CONV	CONV-Z	*P-value*	NAT	CONV	CONV-Z	*P-value*
Juiciness[2]	3.69	3.37	3.58	0.08	3.66[a]	3.57[a]	4.47[b]	<0.01
Tenderness[2]	3.61[b]	3.17[a]	3.54[b]	<0.01	3.25[a]	3.19[a]	4.12[b]	<0.01
Flavor[2]	3.90	3.69	3.89	0.19	3.78[a]	3.78[a]	4.35[b]	0.02
Overall Liking[2]	3.85	3.59	3.81	0.13	6.00[a]	5.91[a]	6.68[b]	<0.01

[a,b] LS means within a row without 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] 1 = like extremely; 2 = like very much; 3 = like moderately; 4 = like slightly; 5 = neither like nor dislike; 6 = dislike slightly; 7 = dislike moderately; 8 = dislike very much; 9 = dislike extremely

CHAPTER IV

EFFECTS OF TECHNOLOGY USE IN BEEF PRODUCTION SYSTEMS ON MUSCLE DIMENSIONS OF STRIP LOINS

ABSTRACT

The objective of this study was to examine the effect of beef production systems with and without the use of a β-adrenergic agonist on muscle conformation of strip loins compared to an all-natural production system. The treatments consisted of all-natural production (NAT), conventional production (CONV), and conventional production with the addition of zilpaterol hydrochloride (CONV-Z). Crossbred beef steers (n = 336) were randomized to one of three treatments and fed for an average of 136 d before slaughtered at Creekstone Farm; Arkansas City, KS. Forty-four carcasses that graded USDA Low Choice were identified for each treatment and loins were cut into 2.54-cm thick steaks. The anterior end of each steak was pictured for muscle dimension measurements using image analysis software. Measurement data were analyzed in the MIXED procedure of SAS with steak number as a repeated measure and were considered significant at P <

0.05. Muscle dimension analysis indicated that *longissimus lumborum* (LL) area was increased in CONV-Z steers compared to CONV steers ($P < 0.01$) and CONV were increased compared to NAT steers ($P < 0.01$). *Gluteus medius* (GM) area was decreased in NAT steers compared to CONV-Z and CONV ($P < 0.01$). The CONV-Z steers trended toward an increased percentage of vein-steaks (strip steaks containing both LL and GM), compared to NAT ($P = 0.06$), although CONV-Z had a numerically greater percentage of vein-steaks compared to CONV steers, they did not differ statistically ($P = 0.18$). No difference ($P = 0.11$) was detected in medial-lateral LL width between CONV-Z and CONV steers, but both showed an increase compared to NAT steers ($P < 0.01$). Maximum dorsal-ventral depth of LL at 25, 50 and 75% length of LL was increased in CONV-Z steers compared to CONV ($P < 0.01$) and NAT steers ($P < 0.01$), with the greatest increases at 25 and 75% depth. Results show improvement in muscle conformation creating a more usable center of the plate steak from the use of efficiency improving technologies. The CONV and CONV-Z production practices result in larger LL areas, mainly shown through increased dorsal-ventral muscle depth economically important to the steak cutting industry.

INTRODUCTION

Technology has become an important aspect in modern beef production as the world population increases and cattlemen are expected to produce more with the same, or fewer resources. The use and development of growth-promotants have had major impacts on cattlemen's ability to do just that. Beta-agonists, steroidal implants, ionophores and antibiotics have had a crucial role in helping cattle feeders to be profitable in the face of an ever-shrinking U.S. cattle inventory, fluctuating corn prices and high beef demand. In the later stages of feeding, when cattle start to deposit more fat than muscle, the use of growth-promoting technologies can help to increase muscle synthesis, ultimately increasing feed efficiency and pounds of lean beef produced.

Capper and Hayes (2012) found the use of growth-promotants have allowed producers to use 265,000 fewer hectares of land, 2.8 million fewer tons of feed and reduce manure output by 1.8 million tons. Despite the major sustainability benefits to using growth-promoting technologies, without the economic aspect they would not be where they are today. As a result of increased performance, beta-agonists and implants provide major economic returns in years where feed and cattle prices are high. Duckett and Pratt (2014) reported implanting cattle in 2013, a year where the average U.S. corn price approached $6.90/bu., yielded an average economic return of $102.62/head. Given the economic, performance and sustainability benefits of growth-promotants, it comes as no surprise that, today, around 45% of feedlot steers are fed a beta-agonist during the finishing phase (NAHMS, 2011). Usage of implants is even higher with approximately 97% of all feedlots steers having received at least one steroidal implant during the finishing stage (NAHMS, 2000).

Given the importance of muscle conformation to the steak-cutting industry, it is important to understand specific muscle conformation changes in beef steers in response to technologies used in production systems. This experiment aims to document changes in strip steak conformation and where those changes occur.

METHODOLOGY

Cattle Management and Study Treatments

Animals were handled in a manner consistent with institutional regulations and standards set forth by the Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching (FASS, 1999).

A feedlot experiment was conducted by Maxwell (2014) to study the effects of production technologies on feedlot performance and carcass characteristics using crossbred beef steers (n = 336) blocked by body weight and randomized to one of three treatments. Treatments consisted of an all-natural treatment (**NAT**), a conventional treatment (**CONV**) and conventional treatment with the inclusion of a beta-agonist (**CONV-Z**). The NAT cattle received no antibiotics or growth-promoting technologies, qualifying for the Creekstone Farm Natural Black Angus Beef brand and premiums. If NAT cattle were found to require antibiotics they were treated and removed from trial. Both the CONV and CONV-Z were fed 33 and 9 mg/kg of monensin and tylosin (Rumensin and Tylan, Elanco Animal Health) daily, respectively. Both were implanted on d 0 with 40 mg estradiol and 200 mg trenbolone acetate (Revalor-XS, Merck Animal Health). The CONV-Z steers also received 6.76mg/kg of zilpaterol hydrochloride (Zilmax, Merck Animal Health) for 20 d before slaughter with a 3-4 d withdraw. All cattle were fed the same base concentrate diet for an average of 136 d as shown in Table 1.

Slaughter

On d 84, steers were separated into slaughter groups based on a visual appraisal of 12^{th} rib fat thickness and projected slaughter weight. Cattle were slaughtered at Creekstone Farms, Arkansas City, KS on September 12 and 13, 2013. The CONV and CONV-Z cattle were slaughtered on Thursday while NAT cattle were slaughtered on Friday due to requirements of the packing facility.

Strip Loin Selection and Preparation

Strip loins (n = 132) were transported from Creekstone Farms to Oklahoma State University and were fabricated into 2.54-cm thick steaks using a gravity slicer (model SE-12, Bizerba USA, Inc., Sandston, VA). Modeling Lawrence et al. (2011), each steak was numbered anterior to posterior and the anterior surface of each steak was scanned (CanoScan LiDE 210, Canon, Tokyo, Japan). Using Assess (American Phytopathology Society, St. Paul, MN) image analysis software, the following measurements were taken: area of the M. *longissimus lumborum* (LL), area of the M. *gluteus medius* (GM), medial-lateral width of LL, and dorsal-ventral depth at 25, 50, and 75% of the medial-lateral width.

Statistical Analysis

Least square means (LSmeans) and standard errors (SE) were generated using the MIXED Procedure of SAS (SAS 9.3; SAS Inst. Cary, NC). Individual animal was used as the experimental unit and strip loins served as the sampling unit. Steak number (cut from the loin anterior to posterior) was used as a repeated measure. For all analyses, when a significant f-test was identified ($P < 0.05$), means were separated using a pairwise t-test. Means were considered significantly different at ($P < 0.05$) and trends were evaluated under ($P < 0.10$).

RESULTS AND DISCUSSION

All muscle conformation results are shown in Table 7. Loin muscle area was affected by treatment ($P < 0.0001$) with CONV-Z steaks having the largest LMA, CONV steaks intermediate, and NAT steaks having the smallest LMA. Compared to the LMA of NAT steaks, CONV steaks were 14.9% larger and CONV-Z steaks were 20.3% larger. The LMA of CONV-Z steaks were 4.7% larger than CONV steaks. In contrast, Lawrence et al. (2011) studied the effects of ZH on muscle conformation of calf-fed Holstein steers and found no difference in LMA of strip steaks from cattle fed ZH and a control. Nonetheless, the results from this study agree with past research showing feeding ZH increased LMA (Avendaño-Reyes et al., 2006; Kellermeier et al., 2009; Baxa et al., 2010).

Gluteus medius area was also affected by treatment with NAT steaks having less GM than CONV and CONV-Z steaks ($P = 0.0049$). Of steaks with GM present, NAT steaks displayed 17.9% less GM area than CONV steaks (($P = 0.0180$) and 22.3% less than CONV-Z steaks ($P = 0.0017$). There was no difference between treatments in the number or percentage of vein-steaks (strip steaks with gluteus medius present) cut from each loin (*P* = 0.14 & *P* = 0.17). Similarly, Lawrence et al. (2011) did not find a difference in the percentage of vein-steaks or GM area.

Treatment was found significant (*P* < 0.0001) on medial-lateral width of LL as well. Although there was no medial-lateral width difference (*P* = 0.1126) between CONV-Z and CONV steaks, CONV steaks were 4.5% longer than NAT steaks (*P* < 0.001), and CONV-Z steaks were 5.9% longer (*P* < 0.0001).

Dorsal-ventral LL muscle depths were significant (*P* < 0.0001) for all three treatments and in all three measures (25, 50, and 75% of the medial-lateral width) CONV-Z steaks were the widest, CONV steaks were intermediate, and NAT steaks were the narrowest. Lawrence et al. (2011) also showed increased dorsal-ventral depth at 25 and 50% of the medial-lateral width, however ZH feeding was not shown significant at 75% of the medial-lateral width.

IMPLICATIONS

Results show improvement in muscle conformation creating a more usable center of the plate steak from the use of efficiency improving technologies. Using CONV and CONV-Z production practices result in larger LL areas, mainly shown through increased dorsal-ventral muscle depth economically important to the steak cutting industry.

Table 8. Least squares means and descriptive statistics of strip steak muscle conformation parameters from beef steers

Item	Treatment			*P-value*	SEM
	NAT	CONV	CONV-Z		
Longissimus area, cm^2	72.99[a]	83.89[b]	87.79[c]	<0.01	0.06
Gluteus medius area, cm^2	14.39[a]	17.53[b]	18.53[b]	<0.01	0.14
Medial-lateral width, cm	15.51[a]	16.21[b]	16.42[b]	<0.01	0.04
Depth 25%[2], cm	4.97[a]	5.48[b]	5.68[c]	<0.01	0.02
Depth 50%[3], cm	5.43[a]	5.79[b]	6.01[c]	<0.01	0.03
Depth 75%[4], cm	5.76[a]	6.33[b]	6.52[c]	<0.01	0.03
Vein steaks[5], %	21.37	21.99	23.29	0.17	0.01

[a,b,c] Within a row, means without a common superscript letter 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] Dorsal-ventral depth of longissimus at 25% of the width from the midline.

[3] Dorsal-ventral depth of longissimus at 50% of the width from the midline.

[4] Dorsal-ventral depth of longissimus at 75% of the width from the midline.

[5] Percentage of strip steaks with gluteus medius present.

REFERENCES

Acheson, R. J., and J. D. Tatum. 2014. Beef Carcass Maturity and Palatability Research. In: Proc. 67th Recip. Meat Conf., Madison, Wisconsin.

Arp, T. S., S. T. Howard, D. R. Woerner, J. A. Scanga, D. R. McKenna, W.H. Kolath, P. L. Chapman, J. D. Tatum, and K. E. Belk. 2013. Effects of ractopamine hydrochloride and zilpaterol hydrochloride supplementation on longissimus muscle shear force and sensory attributes of beef steers. J. Anim. Sci. 91:5989-5997.

ASTM International. 2011. F2025-11. Standard specifications for tenderness marketing claims associated with meat cuts derived from beef. Am. Soc. Testing Materials Int., West Conshohocken, PA.

Avendaño-Reyes, L., V. Torres-Rodríguez, F. J. Meraz-Murillo, C. Pérez-Linares, F. Figueroa-Saavedra, and P. H. Robinson. 2006. Effects of two β-adrenergic agonists on finishing performance, carcass characteristics, and meat quality of feedlot steers. J. Anim. Sci. 84:3259-3265.

Baxa, T. J., J. P. Hutcheson, M. F. Miller, J. C. Brooks, W. T. Nichols, M. N. Streeter, D. A. Yates and B. J. Johnson. 2010. Additive effects of a steroidal implant and zilpaterol hydrochloride on feedlot performance, carcass characteristics, and skeletal muscle messenger ribonucleic acid abundance in finishing steers. J. Anim. Sci. 88:330-337.

Beckett, J. L., R. J. Delmore, G. C. Duff, D. A. Yates, D. M. Allen, T. E. Lawrence, and N. Elam. 2009. Effects of zilpaterol hydrochloride on growth rates, feed conversion, and carcass traits in calf-fed Holstein steers. J. Anim. Sci. 87:4092-4100.

Bergen, W. G., S. E. Johnson, D. M. Skjaerlund, A. S. Babiker, N. K. Ames, R A. Merkel, and D. B. Anderson. 1989. Muscle protein metabolism in finishing pigs fed ractopamine. J. Anim. Sci. 67:2255-2262.

Boler, D. D., A. L. Shreck, D. B. Faulkner, F. K. McKeith, J. W. Homm, and J. A. Scanga. 2012. Effects of ractopamine hydrochloride (Optaflexx) dose on live animal performance, carcass characteristics, and tenderness in early weaned beef steers. Meat Sci. 92:458-463.

Brooks, J. C., B. Below, D. B. Griffin, B. L. Gwartney, D. S. Hale, W. R. Henning, D. D. Johnson, J. B. Morgan, F. C. Parrish Jr., J. O. Reagan, and J. W. Savell. 2000. National Beef Tenderness Survey-1998. J. Anim. Sci. 78:1852-1860.

Bryant, T. C., T. E. Engle, M. L. Galyean, J. J. Wagner, J. D. Tatum, R. V. Anthony and S. B. Laudert. 2010. Effect of ractopamine and trenbolone acetate implants with or without estradiol on growth performance, carcass characteristics, adipogenic enzyme activity, and blood metabolites in feedlot steers and heifers. J. Anim. Sci. 88:4102-4119.

Capper, J. L., and D. J. Hayes. 2012. The environmental and economic impacts of removing growth-enhancing technologies from U.S. beef production. J. Anim. Sci. 90:3527-3537.

Delmore, R. J., J. M. Hodgen, and B. J. Johnson. 2010. Perspectives on the application of zilpaterol hydrochloride in the United States beef industry. J. Anim. Sci. 88:2825-2828.

Duckett, S. K. and J. G. Andrae. 2001. Implant strategies in an integrated beef production system. J. Anim. Sci. 79(E. Suppl.):E110-E117.

Duckett, S. K. and S. L. Pratt. 2014. MEAT SCIENCE AND MUSCLE BIOLOGY SYMPOSIUM-Anabolic implants and meat quality. J. Anim. Sci. 92:3-9.

Duffield, T. F., J. K. Merrill, and R. N. Bagg. 2012. Meta-analysis of the effects of monensin in beef cattle on feed efficiency, body weight gain and dry matter intake. J. Anim. Sci. 90:4583-4592.

Elam, N. A., J. T. Vasconcelos, G. Hilton, D. L. VanOverbeke, T. E. Lawrence, T. H. Montgomery, W. T. Nichols, M. N. Streeter, J. P. Hutcheson, D. A Yates, M. L. Gaylean. 2009. Effect of zilpaterol hydrochloride duration of feeding on performance and carcass characteristics of feedlot cattle. J. Anim. Sci. 87:2133-2141.

Ellis, J. L., J. Dijkstra, A. Bannink, E. Kebreab, S. E. Hook, S. Archibeque, and J. France. 2012. Quantifying the effect of monensin dose on the rumen volatile fatty acid profile in high-grain-fed beef cattle. J. Anim. Sci. 90:2717-2726.

FDA. 2006. Freedom of information summary. Original new animal drug application NADA 141-258. Zilmax (zilpaterol hydrochloride) Type A medicated article for cattle fed in confinement for slaughter. http://www.fda.gov/downloads/AnimalVeterinary/Products /ApprovedAnimalDrugProducts/FOIADrugSummaries/ucm051412.pdf Accessed Mar. 25, 2014.

FDA. 2003. Freedom of information summary. Original new animal drug application NADA 141-221. Optaflexx 45 (ractopamine hydrochloride) Type A medicated article for beef cattle. http://www.fda.gov/downloads/AnimalVeterinary/Products/ApprovedAnimalDrugProducts/ FOIADrugSummaries/ucm118030.pdf Accessed Mar. 25, 2014.

Foutz, C. P., H. G. Dolezal, T. L. Gardner, D. R. Gill, J. L. Hensley and J. B. Morgan. 1997. Anabolic implant effects on performance, carcass traits, subprimal yields, and longissimus muscle properties. J. Anim. Sci. 75:1256-1265.

Garmyn, A. J., J. N. Shook, D. L. VanOverbeke, J. L. Beckett, R. J. Delmore, D. A. Yates, D. M. Allen, and G. G. Hilton. 2010. The effect of zilpaterol hydrochloride on carcass cutabililty and tenderness of calf-fed Holstein steers. J. Anim. Sci. 88:2476-2485.

Garmyn, A. J., S. M. Knobel, K. S. Spivey, L. F. Hightower, J. C. Brooks, B. J. Johnson, S. L. Parr, R. J. Rathmann, J. D. Starkey, D. A. Yates, J. M. Hodgen, J. P. Hutcheson, and M. F. Miller. 2011. Warner-Bratzler and slice shear force measurements of 3 beef muscles in response to various aging periods after trenbolone acetate and estradiol implants and zilpaterol hydrochloride supplementation of finishing beef steers. J. Anim. Sci. 89:3783-3791.

Garmyn, A. J., J. C. Brooks, J. M. Hodgen, W. T. Nichols, J. P. Hutcheson, R. J. Rathmann, and M. F. Miller. 2014. Comparative effects of supplementing beef steers with zilpaterol hydrochloride, ractopamine hydrochloride, or no beta agonist on strip loin composition, raw and cooked color properties, shear force, and consumer assessment of steaks aged for fourteen or twenty-one days postmortem. J. Anim. Sci. 92:3670-3684.

Holt, S. 2009. Beef Tech-Line: Implants. Tech. Bul. Hubbard, Mankato, MN. http://admin.hubbardlife.com/files/files/BeefTechLineMay2009%20Implants.pdf (Accessed 14 September 2014).

Hilton, G. G., J. L. Montgomery, C. R. Krehbiel, D. A. Yates, J. P. Hutcheson, W. T. Nichols, M. N. Streeter, J. R. Blanton Jr., and M. F. Miller. 2009. Effects of feeding zilpaterol hydrochloride with and without monensin and tylosin on carcass cutability and meat palatability of beef steers. J. Anim. Sci. 87:1394-1406.

Johnson, B. J., P. T. Anderson, J. C. Meiske, and W. R. Dayton. 1996. Effect of a combined trenbolone acetate and estradiol implant on feedlot performance, carcass characteristics, and carcass composition of feedlot steers. J. Anim. Sci. 74:363-371.

Johnson, B. J., N. Halstead, M. E. White, M. R. Hathaway, A. DiCostanzo and W. R. Dayton. 1998. Activation state of muscle satellite cells isolated from steers implanted with a combined trenbolone acetate and estradiol implant. J. Anim. Sci. 76:2779-2786.

Johnson, B. J., F. R. B. Ribero and J. L. Beckett. 2013. Application of growth technologies in enhancing food security and sustainability. Animal Frontiers. 3:8-13.

Kellermeier, J. D., A. W. Tittor, J. C. Brooks, M. L. Galyean, D. A. Yates, J. P. Hutcheson, W. T. Nichols, M. N. Streeter, B. J. Johnson, and M. F. Miller. 2009. Effects of zilpaterol hydrochloride with or without an estrogen-trenbolone acetate terminal implant on carcass traits, retail cutout, tenderness, and muscle fiber diameter in finishing steers. J. Anim. Sci. 87:3702-3711.

Lands, A. M., A. Arnold, J. P. McAuliff, F. P. Lunduena, and T. G. Brown Jr. 1967. Differentiation of receptor systems activated by sympathomimetic amines. Nature. 214:597-598.

Lawrence, T. E., D. M. Allen, R. J. Delmore, J. L. Beckett, W. T. Nichols, M. N. Streeter, D. A. Yates, J. P. Hutcheson. 2011. Technical Note: Feeding zilpaterol hydrochloride to calf-fed Holstein steers improves muscle conformation of top loin steaks. Meat Sci. 88:209-211.

Maxwell, C. L. 2014. Advantages of technology use in beef production systems. PhD Diss. Oklahoma State Univer., Stillwater.

Mehaffey, J. M., J. C. Brooks, R. J. Rathmann, E. M. Alsup, J. P. Hutcheson, W. T. Nichols, M. N. Streeter, D. A. Yates, B. J. Johnson, and M. F. Miller. 2009. Effect of feeding zilpaterol hydrochloride to beef and calf-fed Holstein cattle on consumer palatability ratings. J. Anim. Sci. 87:3712-3721.

Mersmann, H. J. 1998. Overview of the effects of β-Adrenergic receptor agonists on animal growth including mechanisms of action. J. Anim. Sci. 76:160-172.

Miller, M. F., M. A. Carr, C. B. Ramsey, K. L. Crockett, and L. C. Hoover. 2001. Consumer thresholds for establishing the value of beef tenderness. J. Anim. Sci. 79:3062-3068.

Moody, D. E., D. L. Hancock, D. B. Anderson. 2000. Phenethanolamine Repartitioning Agents. Pages 65-96 in Farm Animal Metabolism and Nutrition. J. P. F. D'Mello, ed. CAB Int., Wallingford, Oxon, UK.

Montgomery, J. L., C. R. Krehbiel, J. Cranston, D. A. Yates, J. P. Hutcheson, W. T. Nichols, M. N. Streeter, R. S. Swingle, and T. H. Montgomery. 2009. Effects of dietary zilpaterol hydrochloride on feedlot performance and carcass characteristics of beef steers fed with and without monensin and tylosin. J. Anim. Sci. 87:1013-1023.

National Animal Health Monitoring System (NAHMS) 2000. USDA National Animal Health Monitoring System report on implant usage by U.S. feedlots. http://www.aphis.usda.gov/animal_health/nahms/feedlot/downloads/feedlot99/Feedlot99_is_ImplantUsage.pdf (Accessed 14 September 2014).

National Animal Health Monitoring System (NAHMS) 2011. USDA National Animal Health Monitoring System management practices on U.S. feedlots. http://www.aphis.usda.gov/animal_health/nahms/feedlot/downloads/feedlot2011/Feed11_dr_PartI.pdf (Accessed 14 June 2014).

Neely, T. R., C. L. Lorenzen, R. K. Miller, J. D. Tatum, J. W. Wise, J. F. Taylor, M. J. Buyck, J. O. Reagan, and J. W. Savell. 1998. Beef Customer Satisfaction: Role of Cut, USDA Quality Grade, and City on In-Home Consumer Ratings. J. Anim. Sci. 76:1027-1032.

Negaraja, T. G., and M. M. Chengappa. 1998. Liver abscesses in feedlot cattle: A review. J. Anim. Sci. 76:287-298.

Platter, W. J., J. D. Tatum, K. E. Belk, J. A. Scanga and G. C. Smith. 2003. Effects of repetitive use of hormonal implants on beef carcass quality, tenderness, and consumer ratings of beef palatability. J. Anim. Sci. 81:984-996.

Quinn, M. J., C. D. Reinhardt, E. R. Loe, B. E. Depenbusch, M. E. Corrigan, M. L. May, and J. S. Drouillard. 2008. The effects of ractopamine-hydrogen chloride (Optaflexx) on performance, carcass characteristics, and meat quality of finishing feedlot heifers. J. Anim. Sci. 86:902-908.

Savell, J. W., R. E. Branson, H. R. Cross, D. M. Stiffler, J. W. Wise, D. B. Griffin, and G. C. Smith. 1987. National Consumer Retail Beef Study: Palatability Evaluation of Beef Loin Steaks that Differed in Marbling. J. Food Sci. 52:517-519.

Scheffler, J. M., D. D. Buskirk, S. R. Rust, J. D. Cowley, and M. E. Doumit. 2003. Effect of repeated administration of combination trenbolone acetate and estradiol implants on growth, carcass traits, and beef quality of long-fed Holstein steers. J. Anim. Sci. 81:2395–2400.

Schmidt, W. F., R. M. Waters, A. D. Mitchell, J. D. Warthen, I. L. Honigbert Jr., and H. Van Halbeek. 1993. Association of beta-agonists with corresponding beta 2- and beta 1-adrenergic penta-peptide sequences. Int. J. Pept. Protein Res. 41:467-475.

Scramlin, S. M., W. J. Platter, R. A. Gomez, W. T. Choat, F. K. McKeith, and J. Killefer. 2010. Comparative effects of ractopamine hydrochloride and zilpaterol hydrochloride on growth performance, carcass traits, and longissimus tenderness of finishing steers. J. Anim. Sci. 88:1823-1829.

Seideman, S. C., and L. K. Theer. 1986. Relationships of instrumental textural properties and muscle fiber types to the sensory properties of beef. J. Food Qual. 9:251-261.

Shook, J. N., D. L. VanOverbeke, L. A. Kinman, C. R. Krehbiel, B. P. Holland, M. N. Streeter, D. A. Yates, and G. G. Hilton. 2009. Effects of zilpaterol hydrochloride and zilpaterol hydrochloride withdraw time on beef carcass cutability, composition, and tenderness. J. Anim. Sci. 87:3677-3685.

Sillence, M. N. and M. L. Matthews. 1994. Classical and atypical binding sites for beta-adrenergic ligands and activation of adenylyl cyclase in bovine skeletal muscle and adipose tissue membranes. Br. J. Pharmacol. 111:866-872.

Sillence, M. N., J. Hooper, G. H. Zhou, Q. Liu, and K. J. Munn. 2005. Characterization of porcine β_1- and β_2-adrenergic receptors in heart, skeletal muscle and adipose tissue, and the identification of an atypical β-adrenergic binding site. J. Anim. Sci. 83:2339-2348.

Therkildsen, M. and N. Oksbjerg. 2009. Muscle protein turnover. Pages 115-128 in Applied Muscle Biology and Meat Science. M. Du, and R. J McCormick, ed. CRC Press, Boca Raton, FL.

Turner, H. A., R. L. Phillips, M. Vavra, and D. C. Young. 1981. The efficacy of an estradiol-silicone rubber removable implant in suckling, growing and finishing steers. J. Anim. Sci. 52:939

Verhoeckx, K. C. M., R. P. Doornbos, J. Van Der Greef, R. F. Witkamp, R. J. T. Rodenburg. 2005. Inhibitory effects of the β_2-adrenergic receptor agonist zilpaterol on the LPS-induced production of TNF-α *in vitro* and *in vivo*. J. Vet. Pharmacol. Therap. 28:531-537.

Winterholler, S. J., G. L. Parsons, D. K. Walker, M. J. Quinn, J. S. Drouillard, and B. J. Johnson. 2008. Effect of feedlot management system on response to ractopamine-HCl in yearling steers. J. Anim. Sci. 86:2401-2414.

APPENDICES

All procedures involving human test subjects were approved by the Oklahoma State University Institutional Review Board

Trained Taste Panel Ballot

Panelist No. ____________________ Date ____________________ Time ____________________

Sample	Initial Juiciness	Sustained Juiciness	Tenderness (First Impression)	Tenderness (Overall Impression)	Connective Tissue Amount	Beef Flavor	Beef-fat Flavor	Metallic Flavor	Oxidative Flavor
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									

Initial & Sustained Juiciness		Tenderness		Connective Tissue Amount		Flavors/Off Flavor Intensity	
8	Extremely juicy	8	Extremely tender	8	None	8	Very Strong Presence
7	Very juicy	7	Very tender	7	Practically None	7	
6	Moderately juicy	6	Moderately tender	6	Traces	6	
5	Slightly juicy	5	Slightly tender	5	Slight	5	
4	Slightly dry	4	Slightly tough	4	Moderate	4	
3	Moderately dry	3	Moderately tough	3	Slighly abundant	3	
2	Very dry	2	Very tough	2	Moderately abundant	2	
1	Extremely dry	1	Extremely tough	1	Abundant	1	No Presence

Oklahoma State University Institutional Review Board

Date:	Thursday, October 31, 2013
IRB Application No	AG1351
Proposal Title:	Consumer Preference for Beef Strip Steaks
Reviewed and Processed as:	Exempt

Status Recommended by Reviewer(s): Approved Protocol Expires: 10/30/2016

Principal Investigator(s):

Deborah VanOverbeke	Bailey Harsh
104D An. Sci.	107 ANSI
Stillwater, OK 74078	Stillwater, OK 74078

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. Protocol modifications requiring approval may include changes to the title, PI, advisor, funding status or sponsor, subject population composition or size, recruitment, inclusion/exclusion criteria, research site, research procedures and consent/assent process or forms.
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 Dawnett Watkins 219 Cordell North (phone: 405-744-5700, dawnett.watkins@okstate.edu).

Sincerely,

Shelia Kennison, Chair
Institutional Review Board

Sensory Evaluation

Informed Consent Form
Beef Steak Project

The following document contains important research information concerning your participation in this research study. Please read all the information carefully. Your participation in this project is voluntary and you may, at anytime, stop participating without penalty.

1. This research study is being conducted through Oklahoma State University.
2. The purpose of this research study is to determine palatability differences, if any, in steak products.
3. The steaks were made with ingredients at levels approved by FDA and USDA.
4. The samples will be served to you, and you will be expected to evaluate samples and mark a ballot with your impression of the characteristics listed on the ballot.
5. There are no known risks associated with this project which are greater than those ordinarily encountered in daily life.
6. You will be asked to evaluate like/dislike for tenderness, juiciness, flavor and overall like components of the meat products.
7. You will be asked to participate in 1-8 minute sessions
8. You are encouraged to ask any questions about procedures.
9. You will not be asked to make any identifying marks on the ballots and efforts are being made to maintain the confidentiality of your responses.
10. Data will be stored on the investigators computer during analysis and report preparation and then stored on a backup drive for three years. Data will be accessible to the investigators listed on the project.
11. In the case of injury or illness resulting from this study, emergency medical treatment will be available. No funds have been set aside by Oklahoma State University to compensate you in the event of illness or injury.
12. You will be provided with candy and/or breath mints upon completion of each session.

For questions about the research study, contact:
Dr. Deb VanOverbeke
104D Animal Science
Stillwater, OK 74078
405.744.6616 office
deb.vanoverbeke@okstate.edu

This research study has been reviewed and approved by the Institutional Review Board for Human Subjects in Research at Oklahoma State University. If you have questions about your rights as a research volunteer, you may contact Dr. Shelia Kennison, IRB Chair, 219 Cordell North, Stillwater, OK 74078, 405-744-3377 or irb@okstate.edu.

____________________ Deb VanOverbeke, PI

____________________ Participant

Department of Animal Science Oklahoma State University Stillwater, OK 74078

Okla. State Univ.
IRB
Approved 10.31.13
Expires 10.30.16
IRB # AG.13.51

Updated: September, 2013

Oklahoma State University Meat Science Research

Instructions: Please circle a **NUMBER** for each category.

Pink

Tenderness	Juiciness		Flavor	Overall Liking
1	1	Like extremely	1	1
2	2	Like very much	2	2
3	3	Like moderately	3	3
4	4	Like slightly	4	4
5	5	Neither like nor dislike	5	5
6	6	Dislike slightly	6	6
7	7	Dislike moderately	7	7
8	8	Dislike very much	8	8
9	9	Dislike extremely	9	9

Black

Tenderness	Juiciness		Flavor	Overall Liking
1	1	Like extremely	1	1
2	2	Like very much	2	2
3	3	Like moderately	3	3
4	4	Like slightly	4	4
5	5	Neither like nor dislike	5	5
6	6	Dislike slightly	6	6
7	7	Dislike moderately	7	7
8	8	Dislike very much	8	8
9	9	Dislike extremely	9	9

Blue

Tenderness	Juiciness		Flavor	Overall Liking
1	1	Like extremely	1	1
2	2	Like very much	2	2
3	3	Like moderately	3	3
4	4	Like slightly	4	4
5	5	Neither like nor dislike	5	5
6	6	Dislike slightly	6	6
7	7	Dislike moderately	7	7
8	8	Dislike very much	8	8
9	9	Dislike extremely	9	9

Which sample was the most different?

Why?

Marital Status:

Married

Single

Gender:

Male

Female

Current Employment Status:

Full-time employment

Part-time employment

Not employed

Full-time student

Ethnicity:

Caucasian

Hispanic

African-American

Asian

American-Indian

Other

Age:

18-25

26-35

36-45

46-55

56-65

66+

Household Income Level:

< $20,000

$20,000 - $39,999

$40,000 - $59,999

$60,000 - $79,999

$80,000 - $99,999

> $99,999

Household Size (including yourself):

1

2

3

4

5 or more

Beef Consumption:

> 3 times per week

1 – 2 times per week

2 – 3 times per month

once per month

less than once per month

VITA

Bailey Nicole Harsh

Candidate for the Degree of

Master of Science

Thesis: EFFECTS OF TECHNOLOGY USE IN BEEF PRODUCTION SYSTEMS ON MEAT QUALITY, CONSUMER PALATABILITY AND MUSCLE DIMENSIONS OF STRIP LOINS

Major Field: Meat Science

Biographical:

Education: Graduated from Buckeye Valley High School, Delaware, Ohio in May 2009; received Bachelor of Science in Animal Science at The Ohio State University, Columbus, Ohio in 2013; received Master of Science in Meat Science at Oklahoma State University, Stillwater, Oklahoma in December 2014.

Experience: Employee of The Ohio State University Meat Lab, 2011 to 2012; Intern for National Cattlemen's Beef Association, Policy Office at Washington D.C., 2012-2013; Graduate Research Assistant at Oklahoma State University, 2013-2014.

Professional Memberships: American Angus Association, American Meat Science Association, National Cattlemen's Beef Association, Ohio Angus Association, Ohio Cattlemen's Association