EFFECTS OF ZILMAX FEEDING ON MARKET DAIRY COW PERFORMANCE, CARCASS CHARACTERISTICS, CUTABILITY, MUSCLE QUALITY OF SELECTED ADDED VALUE BEEF CUTS, AND SUBCUTANEOUS FAT QUALITY

by

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(Under the Direction of T. Dean Pringle)

ABSTRACT

Thirty-four cull dairy cows were used to investigate effects of zilpaterol hydrochloride (ZH) supplementation on feedlot performance, carcass characteristics, cutability, muscle quality of selected added-value cuts, and subcutaneous fat quality. Feeding ZH had no effect ($P > 0.05$) on ADG, G:F, DMI, BCS, LS, or BW. Feeding ZH increased ($P < 0.05$) REA while having no effect on BF, ribeye ratio, or IMF ultrasound measurements. Feeding ZH caused improvements ($P < 0.05$) in dressing percent, REA, and YG. Zilpaterol hydrochloride had significant effects in increasing primal, subprimal, and cut yields while having no adverse effects on quality. Feeding ZH resulted in less tender steaks that required longer aging times to become comparable to steaks from control (CT) cows. Feeding ZH caused increases ($P = 0.03$) percentages of C18:1, *cis*-9, whereas CT cows had higher ($P = 0.02$) percentages of C14:0. Percentage of PUFA for CT cows tended ($P = 0.09$) to be higher than ZH-fed cows. Zilpaterol hydrochloride is an effective method for improving muscle and leanness of market dairy cows, however, this treatment has not shown any improvements in tenderness.

INDEX WORDS: Zilpaterol, market cow, carcass yield, tenderness, fat quality

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B.S.A., The University of Georgia, 2007

A Thesis Submitted to the Graduate Faculty of The University of Georgia in Partial Fulfillment of the Requirements for the Degree

MASTER OF SCIENCE

ATHENS, GEORGIA

2009

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December 2009

DEDICATION

I would like to dedicate this work to my family, Daddy (Gary), Mama (Sandra), Kim, my grandparents (Granddaddy and Maw Maw Lowe, Maw Maw Hamlin, and Paw Paw). You all have shown the upmost support for me and my work not only during college but life as a whole. I owe each of you so much for teaching me about hard work, dedication, determination, attentiveness, and humility. It was your motivation and support that taught me to understand that success is not always about winning; and the route taken may be just as important.

ACKNOWLEDGEMENTS

I would like to thank the members of my master's committee for their guidance and cooperation during the completion of my degree. To Dr. Dean Pringle, your guidance, attentiveness, and education from the beginning of my undergraduate term through now is greatly appreciated. The dedication and willingness you have shown, not only towards myself, but to each of your students are well welcomed. To Dr. Alex Stelzleni, thank you for being there for any questions I might have had. The time to work with you and Dr. Pringle both is greatly valued, and won't be forgotten. Thank you to Dr. Mark Froetschel for all of the help in preparing for and progress through graduate school.

To Ryan Crowe, even though it has been non-stop since day one, it has been adventurous and one of the best learning experiences of my life. You have taught me so much about cutting meat, but even more about the not so obvious. The life lessons learned from how to teach through how to converse and work with people are taken and well appreciated. We've shared some great and not so great times, but we made it through them, and I thank you for that.

To Mike Mathis and Randy Gabriel, thanks for the patience and hard work during the feedlot portion of this study. To Ms. Gina, your kindness, willingness, and patience in the lab was so helpful. I would also like to thank Jen Safko and my fellow graduate students, Russell McKeith, Jacob Segers, and Rudi Pitzer, for all of their help and friendship.

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CHAPTER 1

INTRODUCTION

Market cows across the country are culled for various reasons including health issues, reproductive failure, or in dairy operations due to a decrease in milk production and (or) milk price. In 2008, cull cows accounted for almost 18% of all beef animals slaughtered (2.7 million dairy cows and 3.6 million beef cows) and the meat from market cows comprised about 14.5% of the beef produced in the United States (USDA-ERS, 2009). A majority of the meat from cull cow carcasses is used for lean trimmings due to low carcass weights, poor muscling, and yellow fat. These characteristics together combine to greatly decrease the value of cull cows. Producers have recently begun to implement short-term feeding regimens in cull cows targeted for the "White Cow" market. This market pays premiums for heavier carcasses that have whiter, more desirable colored fat. These feeding practices have been shown to improve lean color and amount of marbling in market cow carcasses, thus providing more opportunities for foodservice cuts to be higher-valued.

Many producers view market cows as culls and are not taking into consideration the potential revenue to be made from feeding these cows. Market cows are not viewed as an important food source; although in recent years, beef from market cows has been adapted for use in the food service and retail sectors in a variety of forms, other than ground beef. It is reported that concentrate feeding improves muscling and carcass weights of market cows (Cranwell et al., 1996; Price and Berg, 1981; Stelzleni et al., 2007). Smith et al. (1994) reported that producers forfeit approximately $70 of potential revenues per non-fed animal slaughtered in the United States, and that $20 of that could be recovered by feeding cull cows an energy-dense diet prior to

slaughter. Receipts from market cows account for nearly 4% of total returns for the average dairy operation (NCBA, 2007). Furthermore, short-term feeding may have animal welfare benefits particularly in live animal soundness. This could result in fewer problems during transportation and movement to slaughter. Consumer concern over the use and welfare of nonambulatory cows is increasing and there is little information on ways to improve mobility in market cows, especially dairy cows.

Zilpaterol hydrochloride (ZH) is a β2-adrenergic agonist (β-AA), commercially available as Zilmax® (Intervet Schering-Plough Animal Health, Millsboro, DE), that functions as a repartitioning agent. This recently-approved feed additive may offer advantages in carcass yields above those seen with typical slaughter cow feeding programs. Label claims for Zilmax indicate an improvement in ADG, G:F, and an increase in carcass leanness in fed cattle. In addition to cattle performance, Zilmax is reported to increase dressing percent (DP), HCW, ribeye area (REA), and improve YG, while having little or no affect on marbling score (MS) and 12th rib back fat (BF). Thus the inclusion of Zilmax in a short-term feeding regimen may be a way to increase muscling and subprimal cut yields and increase the value of slaughter cows, particularly those heading for the "White Cow" market.

Along with short-term feeding and Zilmax supplementation, advances in fabrication of beef carcasses have led to increased utilization of the chuck and round from cow carcasses. These new "Beef Value Cuts" have created more opportunities for use of beef from the slaughter cow market. Today's consumer continues to demand convenience and quality in meat products. In the past, the primary muscles used for intact, whole-muscle beef were the middle meats (i.e., rib and loin). With the introduction of the Beef Value Cuts, new cuts of beef like the flat iron, out of the chuck, and the tip center, out of the round, have found there way into restaurants and

dining rooms around the country. These new products make beef more interesting to the consumer and most importantly, increase the value of cuts from the otherwise less desirable chuck and round.

CHAPTER 2

LITERATURE REVIEW

The use of metabolic modifiers such as β-adrenergic agonists (β-AA) in livestock species to improve live animal performance and carcass composition has been documented since the 1980's. Improvements in carcass composition with β-AA feeding are due to their effects on metabolism in skeletal muscle and adipose tissue. Synthetic β-AA are similar in structure, biosynthetic sequence, and function to naturally occurring catecholamines (i.e., epinephrine, norepinephrine, and dopamine) produced by mammals (NRC, 1994). The classification and response of β-AA is based upon their binding to specific β-adrenergic receptors (β-AR) found on the exterior of the plasma membrane of the cell.

Zilpaterol hydrochloride is a β2-AA that has been approved for use in finishing cattle in South Africa, Mexico, and most recently, the United States. Zilpaterol hydrochloride acts as a repartitioning agent in cattle and has been shown to enhance lean meat yields. Zilpaterol hydrochloride is commercially available as Zilmax® (Intervet Schering-Plough Animal Health, Millsboro, DE). Label claims for Zilmax indicate an improvement in weight gain and feed efficiency during the finishing phase; and improvements in DP, HCW, REA, and YG, while having little or no effect on MS or BF.

β-AA Mode of Action

As stated earlier, phenethanolamines share common structural qualities, but not all phenethanolamines are β-AA; some are β-adrenergic antagonists, some activate α-receptors, and some are specific for subclasses within each of the α- and β-receptor families (Smith, 1998). Even within the β-AA subfamily, the chemical and pharmokinetic distinctiveness of a specific

agonist may vary significantly from another β-AA. Most phenethanolamines have the following similar structures: an aromatic ring with three binding sites at the end of a carbon chain, a hydroxyl group on the β-carbon, an aliphatic group adjacent to the α-carbon, and an R group adjacent to the aliphatic nitrogen. In ractopamine (RAC), the aromatic ring only has –OH bound at the para- position whereas in ZH, there are two more ring systems formed off of the α-carbon and joined to the aromatic ring. Furthermore, the R-group for RAC is an alkylphenol group compared to an isopropyl group for ZH. It was proposed by Easson and Stedman (1933) that β-AR bind β-AA at three points on the molecule: the β-hydroxyl group, the aliphatic nitrogen, and the aromatic ring. Site directed mutagenesis of β-AR has validated this by showing that specific amino acids within the β-AR are responsible for interacting with the charged aliphatic amine, substituents of the aromatic ring, and β-hydroxyl groups of the β-AA (Wallis, 1993; Hieble et al., 1995). The physiological activity of β-AA is dependent on its innate activity at the receptor and on its absorption, rates of metabolism and elimination, and distribution to target tissues.

There are three subtypes of β-AR, namely, β1-AR, β2-AR, and β3-AR; the pharmacological and physiological responses of an individual cell result from the particular mixture of the three β-AR subtypes present on the cell (Mersmann, 1998). However, the proportions of the three subtypes vary between different tissues within a species. Based on ligand-binding studies, bovine skeletal muscle has almost exclusively β2-AR (Sillence and Mathews, 1994), whereas bovine (Sillence and Mathews, 1994; Van Liefde et al., 1994) and ovine (Bowen et al., 1992) adipose tissue have primarily β2-AR. Therefore, depending on the cell type and subtype of β-ARs present on that cell, the effects of one specific β-AA may not have as pronounced of an effect on both tissues. The β-AR subtypes can be distinguished by their intracellular domains, such that, β_1 and β_2-AR have long intracellular domains compared to

β_3-AR that have short intracellular domains (Mills and Mersmann, 1995). According to Oscar (1995), β-AA are ligands for G-protein-coupled β-ARs. G proteins are a universal means of signal transduction in higher organisms, activating many hormone-receptor-initiated cellular processes in addition to adenylyl cyclase (Garret and Grisham, 2007). The overall effect of β-AA is a chain reaction that is initiated by the binding of the β-AA to the β-AR, which in turn, activates the G_s protein. After activation, the α-subunit of the G_s protein activates adenylyl cyclase. Adenylyl cyclase is the enzyme that produces cyclic adenosine monophosphate (cAMP), a major intracellular signaling molecule. It is understood that the cAMP receptor protein (CRP) is an activator of transcription (Garret and Grisham, 2007). The cAMP binding to the CRP causes the DNA to change shape and simplify the binding of RNA polymerase to the promoter and initiate transcription. This increase in cAMP also causes the activation of protein kinase-A (PKA).

With changes in transcription due to β-AA binding, different tissues react in different ways to the stimuli. With changes in physiological state of the animal under stress, catecholamines are released, and cause a shift to a glycolytic energy sources. One of the second-hand effects of increased epinephrine levels is an increased mobilization of stored energy, adipose. There are effects of β-AA on protein metabolism as well. Although to different extents, different β-AA have pronounced effects on each of these metabolisms.

β-AA and Adipose Metabolism

Ligands for β-AR were first investigated for their anti-obesity properties, so it is presumed that adipose tissue accretion should decrease under β-AA binding and the associated cellular responses. β-AA regulate lipid turnover via both fatty acid synthesis and fatty acid β-oxidation (Ricks et al., 1984). It is important t to understand the mechanics of lipid metabolism

in order to comprehend the effects β-AA can have on mobilization and accretion of fat in the body.

Utilizing Acetyl-CoA, derived from glucose during glycolysis, the tricarboxylic acid (TCA) cycle converts acetyl-CoA to citrate. Citrate is then converted back to acetyl-CoA, by the enzyme ATP citrate lysase, which is now available in the cytoplasm for fatty acid biosynthesis. This acetyl-CoA is then converted to malonyl-CoA through the addition of CO_2 and breakdown of adenosine triphosphate (ATP). Acetyl-CoA carboxylase (ACC), a biotin dependent enzyme, drives the formation of malonyl-CoA. Malonyl-CoA is then utilized as the basic fatty acid chain forming unit.

The ACC complex is regulated by two different systems, polymerization and hormonal or phosphoregulation. During phosphoregulation, protein kinase-C (PK-C), which is activated by glucagon and inhibited by insulin, phosphorylates the more active dephosphorylated ACC to the less active phosphorylated ACC. The active form of ACC is activated by low citrate concentrations whereas the inactive form is activated by high citrate concentrations.

Since fatty acids stored in adipose tissue represent more than 80% of the body's stored energy, they are easily mobilized and utilized for energy. The basic form of this stored energy is triacyl glyceride (TAG), which is made up of a glycerol molecule with three fatty acids (FA) attached. During FA β-oxidation (FA β-OX), TAGs found in the adipose tissue are broken down to release glycerol and fatty acids, via TAG lipase. This TAG lipase is cAMP-dependent and activated by glucagon and epinephrine. Glycerol from TAG enters into glycolysis and produces ATP. The free FA enters the outer membrane of the cell and is converted to acyl-CoA, derivative of energy, via acyl-CoA synthetase.

From earlier, it is known that β-AA act similar to epinephrine (NRC, 1994). Direct activation of β-AR in adipose tissue along with increased PK-A leads to activation and translocation of hormone sensitive lipase and triglyceride hydrolysis. Activation of PK-A is also anti-lipogenic due to phosphorylation and inactivation of glucose transport and acetyl-CoA carboxylase and reduced expression of lipogenic genes (Mills and Mersmann, 1995; Mersmann, 1998). β-AA affect lipid metabolism via hormonal regulation in two different ways, increased β-OX and decreased FA synthesis. The effect β-AA have on cAMP concentrations, correlates with the increased β-OX discussed earlier.

Development of adipocytes in tissue begins with fibroblastic cells dividing, also referred to as proliferation. After proliferation, cells begin to fill with lipid and divide until they contain too much lipid to divide any further (Smith et al., 2004). It is understood that adipocytes increase in animals by hypertrophy and hyperplasia (Smith et al., 2004), but it is not fully understood which one is effected by β-AA. When comparing different β-AA and their effect on adipose tissue it is important to understand that different agonists aren't fully one subtype. Clenbuterol is almost completely a β2 compared to RAC which is a β1/partial β2-AA in bovine adipose tissue. Thornton et al. (1985) found that clenbuterol strongly stimulated lipolysis and inhibited fatty acid synthesis in ovine adipose tissue; similar results were found when evaluating RAC in porcine adipose tissue (Liu et al., 1989).

β-AA and Protein Metabolism

Protein turnover in muscle is a balance between protein synthesis and protein degradation. Protein turnover decreases an animal's growth efficiency due to the energy lost during the breakdown and resynthesis of proteins (Pringle et al., 1993). Protein synthesis (biosynthesis) often refers to only protein translation but more often the process refers to a multi-

step process starting with amino acid synthesis and transcription of nuclear deoxyribonucleic acid (DNA) into messenger ribonucleic acid (mRNA) which is then used as input for translation. In discussion, we will be more concerned with the latter. During transcription, the mRNA chain is produced using one strand (the template strand) of the DNA double helix found in the nucleus. Once the mRNA is formed, it exits the nucleus and enters the cytoplasm of the cell, where it binds to a ribosome subunit, which in turn triggers transfer RNA (tRNA) to be drawn towards the ribosome. The mRNA is then decoded for the specific amino acid sequence which makes up part or all of a peptide chain of the protein.

Treatment of animals with β-AA causes an increase in the amount of mRNA transcript for several skeletal muscle proteins (Mersmann, 1998). Specifically, the mRNA for contractile proteins such as myosin light chain (Smith et al., 1989) and α-actin (Helferich et al., 1990; Koohmaraie et al., 1991; Grant et al., 1993) are increased after β-AA treatment. Increased mRNA levels usually results in increased protein accretion, through increased protein synthesis. Similarly, Baxa (2009) reported similar results of increased myosin mRNA in beef longissimus muscle when ZH was fed to cattle.

Although, there is a general increase in protein synthesis, different muscle fiber types react differently to β-AA. Studies show that type II (fast-glycolytic) fibers are most responsive to β-AA administration in sheep and cattle (Beermann et al., 1987; Miller et al., 1988). Baxa (2009) found that ZH, in particular, causes a decrease in type IIA (high-oxidative, moderate-glycolytic) and an increase in type IIX (low-oxidative, high-glycolytic) myosin heavy chain mRNA. The result is a shift from a smaller diameter, more tender fiber type to a larger diameter, less tender type.

Zilpaterol and other β-AA also have an effect on protein degradation. Calcium-dependent proteinases are needed for protein breakdown during protein turnover. The calpain/calpastatin system is responsible for this proteolysis in the living tissue as well as postmortem (Lawrie and Ledward, 2006). The effects of postmortem proteolysis are referred to as aging, and result in improved tenderness. Both m- and μ-calpain are calcium-dependent, or calcium-activated, proteinases. Calpains do not degrade proteins to free amino acids, but to smaller polypeptide subunits (Lawrie and Ledward, 2006). Although, contractile proteins are not degraded by calpains, structural proteins like those found on the z-disk, α-actinin is released but not degraded, and there is an appearance of a 30 kD and a 95 kD subunit from the degradation of troponin-T. This proteolysis of troponin-T is highly correlated with increased tenderness (Penny and Dransfield, 1979). Postmortem, the free calcium found in the muscle activates calpains (~100 μm for μ- and ~17 mm for m-), but it also activates calpastatin. The calpains are inhibited by the protein calpastatin (Lawrie and Ledward, 2006). The helical sequences of calpastatin prevent calpains from binding to membranes (Mellagren et al., 1989). It is understood that tenderness increases to a greater extent during postmortem storage in muscles that have increased calpain (especially μ-calpain) and (or) decreased calpastatin activities. β-AA feeding is known to increase calpastatin activity, decrease calpain activity, and collectively decrease tenderness. Wheeler and Koohmaraie (1992) reported that fractional protein degradation of skeletal muscle myofibrillar protein was 27% lower in $L_{644, 969}$ treated steers; and Pringle et al. (1993) concurred, reporting that calpastatin and μ-calpain activity was increased and decreased, respectively, in lambs administered $L_{644, 969}$. Zilpaterol had a similar effect on calpastatin mRNA abundance in cattle, causing an increase after 20 days of supplementation and decreasing back to normal levels after 40 days (Rathmann et al., 2009).

β-AA Effects on Performance and Carcass Yield

In feedlot operations, body weight (BW), average daily gain (ADG), feed intake, and feed efficiency (G:F) are traits that affect the time that steers spend on feed and, therefore, profitability (Avendano-Reyes et al., 2006). As previously stated, β-AA is known to decrease fat deposition and increase muscle accretion in many species. This partitioning of absorbed nutrients toward muscle protein accretion would be expected to improve efficiency of gain because the energy required to produce muscle is less than that required to produce fat (Van Es, 1977). It is evident, from literature, that addition of β-AA to diets has positively enhanced performance of cattle with improvements in ADG, G:F, and overall BW (Vestergaard et al., 1994; Schroeder et al., 2004; Dunshea et al., 2005). The effects of β-AA have been shown to be more pronounced in early stages of treatment, and diminish over time (Moloney et al., 1990; Pringle et al., 1993). Steers fed ZH have shown increased body weights and improved ADG (Avendano-Reyes et al., 2006) when compared to controls; and Harborth (2006) reported a tendency for cows fed RAC to have greater body weight gains. It has been reported that large dairy cows are at a disadvantage to moderate-sized beef cows for feed efficiency due to larger BW at the start of a feeding period, which is directly correlated to feed efficiency (Basarb et al., 2003). Holmer et al. (2005) and Allen et al. (2009) concluded that no performance advantage of RAC was observed with RAC feeding in market cows due to the extreme variability in weight and condition of those cows.

A key element in finishing cattle operations is the use of steroidal implants prior to administering β-AA. Steroidal implants such as testosterone propionate, estradiol (E2), zeranol, trenbolone acetate (TBA), or a combination aid in satellite cell proliferation which allows for increased protein synthesis and hypertrophy by acting as a DNA source for protein replication.

Neill et al. (2009) reported no differences in performance between cull beef cows treated with ZH and controls, however, cows that were implanted (200 mg TBA and 20 mg E2) and fed ZH had increased gains compared to controls and ZH fed without an implant. In comparison, cows that were concentrate-fed and implanted had improved growth performance over cows that were concentrate-fed only and cows that were concentrate fed with ZH (Neill et al., 2009).

In finished cattle, β-AA feeding has been shown to have effects on yield determining carcass characteristics such as increased DP, HCW, and REA while reducing backfat (Avendano-Reyes, 2006; Moloney et al., 1990; Elam et al., 2009). When evaluating the effects of RAC feeding in cows, there have been no treatment effects on HCW, DP, or REA (Holmer et al., 2005; Dijkhuis et al., 2008; Allen et al., 2009). Boler et al. (2009) reported that ZH significantly increased subprimal weights and cutting yields in the round, loin/flank, rib/plate, and chuck of calf-fed Holstein steers when fed for at least 20 days prior to slaughter, with the greatest impact occuring in the round. Neill et al. (2009) also reported increases in subprimal weights for cull beef cows fed ZH for 34 days; however, Allen et al. (2009) reported that market dairy cows supplemented with RAC had no changes in strip loin, inside round, trim, and cutout weights. Increases in yields appear to be a result of increased protein synthesis and decreased protein degradation. It is also reported that β-AA-fed cows have larger type 1 fibers than their control counterparts (Gonzalez et al., 2007); therefore, it is plausible that an increase in fiber size can account for increases in REA and increased subprimal and trimmed weights associated with β-AA feeding in cattle.

In feeding market dairy cows, it is important to evaluate both lameness and body condition score (BCS). The problem of lameness in market dairy cows in the United States is substantial and widespread, based on evidence that 49% of dairy cows evaluated immediately

prior to slaughter during the 2007 Market Cow and Bull Quality Audit were classified as lame (NCBA, 2007). Lameness can result in increased trim loss and less saleable product (NCBA, 2007) in addition to an increased likelihood of a cow becoming nonambulatory. Allen et al. (2009) reported that after removing the physiological stress of lactation and the physical stress of walking to the milking parlor several times daily, preslaughter feeding for 90 days improved lameness scores by reducing or removing lameness problems. Cattle producers recognize the significance of external fatness, or body condition, on cowherd fertility, productivity, and profitability (Dziuk and Bellows, 1983; Richards et al., 1986). It is reported that feeding market beef and dairy cows for at least 28 days improves BCS (Schnell et al., 1997), and Apple et al. (1999) reported that cows with a BCS of 6 (on a scale of 1-9) have the greatest potential to maximize total lean product yields.

β-AA Effects on Carcass Quality

Fresh meat color is an important quality characteristic and is the most critical factor in consumer preference and acceptability at purchase. Fresh meat color is typically measured with colorimeters or subjective color standards adopted by the meats industry. Colorimeters measure and quantify light reflectance on three values, L*, a*, and b*. L* is a measure lightness, a* measures red to green, and b* measures yellow to blue. In addition, colorimeter measurements can be used to develop an estimate for chroma (C*) and hue angle (h°) based on a* and b* values. Feeding β-AA is shown to have no effect on lean color scores of finishing steers (Avendano-Reyes et al., 2006; Elam et al., 2009), cows (Dijkhuis et al., 2008; Neill et al., 2009), and market dairy cows (Allen et al., 2009); although, preslaughter feeding has shown improvements in lean maturity scores (Boleman et al., 1996; Allen et al., 2009) for market cows.

Along with lean color, fat color is also a concern in discussing cull cow carcasses. Fat color is an increasingly important trait of consumer interest, and packing plants are beginning to offer a premium for carcasses with whiter fat (NCBA, 2007). Over time, grazing cows begin to develop a yellowish subcutaneous fat color in response to the accumulation of beta-carotene found in forages. Stelzleni et al. (2007) and Allen et al. (2009) reported concentrate feeding to cull cows improved fat color; however, β-AA supplementation seems to have minimal effect on fat color in cows (Allen et al., 2009; Neill et al., 2009).

In addition to color, marbling score (MS) is also used as an indication of quality. Marbling score is a subjective evaluation of longissimus intramuscular fat percentages (IMF) which is an indication of eating quality. Elevated IMF affects beef quality through several mechanisms. First, elevated IMF causes a decrease in strain when eating, due to fat requiring less bite force than muscle. Secondly, fat acts as a lubricant and induces saliva production which helps to reduce the resistance in chewing and improve beef tenderness. Lastly, fat acts to reduce the negative effects of overcooking in meat products by reducing the protein – protein interactions that form as proteins harden in response to heating. Since IMF is the most metabolically active fat depot in the body, it is expected that β-AA feeding would cause a decreases in MS. Elam et al. (2009) reported that ZH caused a decrease in MS for fed cattle; however, Neill et al. (2009) found that ZH had no effect on MS in mature cows. Other β-AA such as $L_{644,969}$ and RAC also seem to have little effect on MS in steers and market dairy cows, respectively (Wheeler and Koohmaraie, 1992; Allen et al., 2009).

β-AA Effects on Tenderness

Tenderness is considered very critical when evaluating eating experiences of fresh meat, and is typically ranked as the most important factor in determining consumer satisfaction with

meat products. Many factors influence tenderness, such as, diet, processing methods, and postmortem proteolysis, or aging. Supplementation of β-AA has been shown to increase Warner-Bratzler shear force (WBSF), an instrumental measure of tenderness, and reduceconsumer sensory scores (Hilton et al., 2009; Leheska et al., 2009). Studies have reported that supplementation of β-AA can increase WBSF from 7 to 300%. Clenbuterol supplementation has been shown to increase WBSF of beef steers and heifers from 14% to 113% when fed 35 to 50 d (Miller et al., 1988; Schiavetta et al., 1990). It has also been reported that $L_{644, 969}$ increases WBSF in lambs (Pringle et al., 1993). Schroeder et al. (2003) reported a 12% increase in WBSF when beef steers were supplemented with RAC. Brooks et al. (2009) reported that ZH feeding for at least 20 d increased WBSF of longissimus, gluteus medius, and triceps brachii steaks. However, there was no treatment × aging interaction. It has been documented that postmortem proteolysis improves tenderness primarily through activity of the calpain system. Strydom and Nel (1996) reported a decrease in shear force when steaks from ZH treated cattle were aged from 7 to 14 d. Buys and Strydom (2000) observed a 10% improvement in shear force when steaks from ZH animals were aged 3 to 10 d postmortem. In addition, Hilton et al. (2009) reported WBSF significantly declined from 7 to 21 d postmortem among steaks from animals supplemented with ZH for 30 d.

In reference to cull cow feeding, Boleman et al. (1996) reported that preslaughter feeding of cull cows resulted in decreased WBSF values when they were fed a concentrate diet for 56 d. Dijkhuis et al. (2008) reported inconsistent results when measuring the effects of different levels of RAC supplementation on tenderness in various muscles from cull cows; however, it was reported that infraspinatus and semimembranosus steaks from RAC supplemented cows had higher WBSF values. It has also been reported that RAC supplementation in cows causes an

increase in muscle fiber diameter (Gonzalez et al., 2007, which should result in reduced tenderness. Also stated earlier, β-AA supplementation has been shown to cause a shift from the smaller-diametered, more tender type IIA muscle fibers to the larger-diametered, less tender type IIX (Baxa, 2009) in the muscle of treated animals. Therefore, cows supplemented with ZH should have increased WBSF values due to increased fiber diameter caused by increased protein synthesis and decreased protein degradation, which would also reduce the level of postmortem proteolysis and reduce the aging response of tenderness.

Conclusions

With the recent approvals of such β-AA as RAC and ZH, for use in beef cattle, beef production has become more efficient and cost effective. Positive effects for both RAC and ZH on live performance and carcass composition and yield have been documented, although consumer acceptability is still elusive due to their effects on tenderness. Market cow preslaughter feeding is not a new concept in the U. S. cattle industry, but new techniques such as the use of β-AA like RAC and ZH have offered new avenues to increase profitability. Feeding ZH and increasing lean meat yields, for both producers and packers, from market cows is only viable if there is a grid system created to pay for improved carcass yields in β-AA fed cows.

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Chapter 3

EFFECTS OF ZILMAX FEEDING ON MARKET DAIRY COW PERFORMANCE, CARCASS CHARACTERISTICS, AND CUTABILITY

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ABSTRACT

Thirty-four market dairy cows (predominately Holstein breeding) were utilized to determine the effects of concentrate feeding and zilpaterol hydrochloride (ZH) on growth performance, carcass characteristics, and carcass yields. Cows, 2 replicates (n = 17 per replicate), were stratified by weight and randomly assigned to 2 treatments: concentrate feed for 42 d (CT) or concentrate feed for 42 d with ZH (7.5 ppm) from d 19-39 followed by a 3 d withdrawal. Over the course of the feeding period, BCS, locomotion score (LS), growth performance, and ultrasonic measurements for ribeye are, 12th rib fat thickness (BF), ribeye ratio (depth:length), and intramuscular fat % were obtained. Cows were harvested at the end of the feeding period and USDA YG and QG data were collected after a 48 h chill (-2°C). Cold side weights (CSW) were recorded and carcasses were fabricated into primals, subprimals, and select added-value cuts. Carcass yields were expressed on a weight and a percentage of CSW basis. Data were analyzed using a one-way ANOVA with replication. Feeding ZH had no effect ($P > 0.05$) on ADG, G:F, DMI, BCS, LS or BW. For ultrasonic measurements, ZH increased ($P < 0.01$) REA, but had no effect ($P > 0.05$) on BF, ribeye ratio, or IMF. Feeding ZH resulted in carcasses with higher ($P = 0.01$) dressing percentages, larger ($P < 0.01$) REA, and improved ($P = 0.01$) YG. No quality traits were affected by ZH supplementation; however ultimate pH for carcasses from ZH-fed cows tended ($P = 0.09$) to be higher. Weights for the shoulder tender, arm roast, shoulder center, brisket flat, tenderloin, cap off top round, eye round, knuckle, peeled knuckle, and tip center were greater ($P < 0.05$) for carcasses from ZH-fed cows; and weights of the whole brisket, rib roll, strip loin, top butt, primal round, top round, and tip side tended ($P < 0.10$) to be higher for carcasses from ZH-fed cows. As a percentage of CSW, shoulder tender, shoulder center, cap-off top round, eye round, and total subprimal percentages were higher ($P <$

0.05) for carcasses from ZH-fed cows than from CT cows; and percentages for shoulder top, brisket flat, rib roll, tenderloin, boneless strip loin, top round, and total primals tended ($P < 0.10$) tended to be higher for carcasses from ZH-fed cows than CT cows. Zilpaterol had significant effects in increasing carcass yields while having no adverse effects on quality in this study, proposing that the inclusion of ZH in a preslaughter feeding regimen could have potential for increasing returns of market dairy cows.

Key words: zilpaterol, market cow, performance, carcass yield

INTRODUCTION

Market cows across the country are culled for various reasons including health issues, reproductive failure, or in dairy operations due to a decrease in milk production and (or) decrease in milk prices. In 2008, cull cows accounted for almost 18% of all beef animals slaughtered (2.7 million dairy cows and 3.6 million beef cows) and the meat from market cows comprised about 14.5% of the beef produced in the United States (USDA-ERS, 2009). A majority of the meat from cull cow carcasses is used for lean trimmings due to low carcass weights, poor muscling, and yellow fat. These characteristics combine to greatly decrease the value of cull cow carcasses. Producers have recently begun to implement short-term feeding regimens in cull cows targeted for the "White Cow" market. These feeding practices have been shown to improve the consumer acceptability of cull cow carcasses, thus adding value to a once low valued commodity.

Zilpaterol hydrochloride (ZH) is a β_2-adrenergic agonist (β-AA), commercially available as Zilmax® (Intervet Schering-Plough Animal Health, Millsboro, DE), that repartitions nutrients toward lean accretion. Supplementation with this recently-approved feed additive may offer advantages in carcass yields above those seen above simple concentrate feeding programs. Label claims for Zilmax® has been shown to increase ADG, G:F, and carcass leanness in fed cattle. In addition to cattle performance, Zilmax® is reported to increase DP, HCW, ribeye area (REA), and improve YG while having little or no affect on marbling score (MS) and 12^{th} rib back fat (BF). Thus the inclusion of Zilmax® in a short-term feeding regimen may be a way to increase muscling and subprimal cut yields and increase the value of market dairy cows, particularly those intended for the "White Cow" market.

Furthermore, short-term feeding may have animal welfare benefits particularly in animal mobility. Inadequate muscling, poor BCS, and lameness can reduce carcass weight, price, and profit derived from market cows (NCBA, 1999). This improved mobility could result in fewer problems during transportation and movement to slaughter and reduce consumer concerns over the welfare of market cows. Therefore, the objectives of this experiment were to evaluate the effect of a short-term feeding, with or without ZH, on market dairy cow welfare, performance, carcass traits, and primal and subprimal yields.

MATERIALS AND METHODS

All animal use and handling techniques described herein were approved by the University of Georgia Animal Care and Use Committee.

Cattle and Dietary Treatments

Thirty-four cull dairy cows, of predominantly Holstein breeding, were used in this study to investigate the effects of ZH supplementation on animal mobility; feedlot performance; carcass yield and quality traits; and primal, subprimal, and select value cut yields. Cows were purchased from a local dairy in the northeast Georgia and a dairy in southwest South Carolina. Upon arrival at The University of Georgia Wilkins Beef Unit in Rayle, GA, cows were treated with an orally-administered anthelmintic; a 7-way clostridia vaccine; a broad spectrum vaccine (IBR, PI3, BVD, BRSV, and Lepto); weighed; and ear tagged. Cows were held on pasture (native Bermuda) during a quarantine period of 21 d. During this period, cows were observed for any issues that might hinder their performance in the study, such as lameness or health problems.

Cows that were deemed acceptable for the study were stratified by weight and randomly assigned to one of two treatments: 1) a concentrate fed diet for 42 d (CT), and 2) a concentrate

fed diet for 42 d with supplementation of ZH (Zilmax®, Intervet Schering-Plough, Millsboro, DE) from d 19-39 followed by a 3 d withdrawal. Cows were implanted in the left ear with Revalor-200 (200 mg of trenbolone acetate and 20 mg of estradiol; Intervet Schering-Plough, Millsboro, DE) on d -7. Cows were fed a diet made up of regionally available feedstuffs (**Table 3.1**) where the overall diet contained 58.5% TDN and 12.7% CP. Zilmax was received as a pelleted pre-mix that contained 320 g Zilpaterol HCl / ton of pelleted wheat middlings. The pre-mix was added to the diet at the rate of 2.12%, which resulted in 7.5 ppm of active ingredient. The feed and pre-mix was mixed in data ranger (5 min) and fed in a Calan gate system. Cows not receiving ZH received additional pelleted wheat middlings at the rate of 2.12% mixed into the diet. Feed analysis showed that ZH were within acceptable levels for ZH diet and that no ZH was present in the CT diet. Feed refusal was measured weekly and feed intake calculated. Live animal data collection included locomotion scoring (LS), BCS, weight, and ultrasound measurements taken on days 0, 19, and 42. A 5-point scale with half point increments was used for BCS (where 1 = extremely emaciated and 5 = extremely over conditioned; Wildman et al., 1982). For LS, the Zinpro (Zinpro Corporation, Eden Prairie, MN) 5-point scale locomotion scoring system was used (where 1=normal or no signs of lameness and 5=severely lame). Ultrasound images for ribeye area (REA), 12th rib backfat (BF), ribeye ratio (ribeye depth:length), and intramuscular fat percentage (IMF) were collected by a certified technician and interpreted using the Beef Images Analysis software (Designer Genes Inc., Harrison, AR).

Harvest and Grading

At the conclusion of feeding, cows were transported to The University of Georgia Meat Science and Technology Center in Athens, GA where they were allowed free access to water prior to harvest. Cows were harvested, under inspection, according to industry standards.

Slaughter weights and hot carcass weights were collected. After a chill period (-2°C) of 48 hours, carcasses were ribbed at the 12th/13th rib juncture and USDA yield and quality data were, collected along with ultimate pH. Ultimate pH was measured with a portable pH meter equipped with a spear tip probe (Oakton pH 11 Series, Oakton Instruments, Vernon Hills, IL) and taken on the 12th rib face of the longissimus muscle. In addition, Hunter L*, a*, and b* values were collected on the 12th rib lean surface and subcutaneous fat color was measured in the 10th to 12th rib region of the carcass approximately 15 cm off the midline. Fat color was also measured subjectively on a 5-point scale, where 1 = white and 5 = dark yellow.

Carcass Fabrication and Yield

Left sides were fabricated into primals, subprimals, and boneless closely trimmed cuts according to the guidelines of the North American Meat Processors (NAMP) Association (NAMP, 2007). Chilled side weights were recorded prior to fabrication to determine chill shrink and yields. The sides were fabricated into primals and weights collected. For final product weights, fat was trimmed to 0.64 cm.

The forequarter and hindquarter were separated between the 12th and 13th ribs, and the rib and plate were then separated from the chuck and brisket by cutting between the 5th and 6th ribs perpendicular to the backbone. The chuck and brisket were further fabricated into the 114 shoulder clod, 120 whole brisket, and 116A chuck roll. The 114 shoulder clod was fabricated to yield a 114D top blade, a 114F shoulder tender (*teres major)*, and a 114E arm roast, which was later divided into the shoulder top (*triceps brachii lateral head*) and the shoulder center (*triceps brachii long head*). The 120 whole brisket was fabricated to yield the 120A brisket flat. The 103 rib primal was separated from the plate and fabricated into a 112A boneless ribeye roll and weighed.

The primal flank was fabricated to yield the 193 flank steak and weighed. The 172 primal loin was fabricated to yield the 189A full tenderloin, 175 short loin, and 181 sirloin. The 175 short loin was fabricated to yield the 180 boneless strip loin and the 181 sirloin was fabricated to yield the 184 boneless top butt. The round was fabricated into the 168 top round, 170 bottom round (gooseneck), and 167 knuckle (tip). The 168 top round was fabricated to the 169D top round, side off, cap off. The 170 bottom round was fabricated to yield the 171B outside flat and the 171C eye round. The 167 knuckle was fabricated into the 167A peeled knuckle, which was divided into the 167E tip center (*rectus femoris*) and the 167F tip side (*vastus lateralis*).

Statistical Analysis

Data were analyzed using the GLM procedure (SAS Inst. Inc., Cary, NC). Animal was the experimental unit for all variables measured in the trial. Treatment (CT and ZH) means were generated and separated using the LSMEANS and PDIFF options. For growth performance data, on test BW and BF were used as covariates. Differences were deemed significant at $P < 0.05$ and tendencies at $P < 0.10$.

RESULTS AND DISCUSSION

Growth Performance

Feeding ZH (7.5 ppm) for the last 20 days of feeding had no effect ($P > 0.05$) on growth performance of market dairy cows. This included ADG for the final 23 d, overall ADG, G:F for the last 23 d, overall G:F, DMI for the last 23 d, and overall DMI (**Table 3.2**). Most studies in fed cattle have reported improvements in ADG and G:F (Elam et al., 2009; Avendano-Reyes et al., 2006) with the inclusion of ZH but that was not the case in feeding slaughter dairy cows in this study. The data from this study is similar to other market cow studies. Allen et al. (2009)

reported no differences when measuring the effects of ractopamine (RAC) on growth traits in market dairy cows; similarly, Neill et al. (2009) reported no differences when market beef cows were administered ZH for 34 d. It has been reported that large-framed dairy cows are at a disadvantage to moderate-sized beef cows for feed efficiency (Basarb et al., 2003) and that BW is critical in effecting feed efficiency due to the amount of feed needed to meet maintenance requirements. Holmer et al. (2005) and Allen et al. (2009) both concluded that no advantage of RAC treatment was observed due to extreme variability associated with feeding both market beef and dairy cows, respectively. Similar findings in our study indicate that large fluctuations in feed intake and growth could be in response to such large body weights and the amount of energy required for maintenance.

Results for BCS, LS, and BW over the course of the trial can be found in **Table 3.2**. Feeding ZH had no effect ($P > 0.05$) on LS, BCS, or BW over the course of the feeding period. The problem of lameness in U. S. market dairy cows in the is common and persistent, based on evidence that 49% of dairy cows evaluated immediately prior to slaughter were classified as lame (NCBA, 2007). Lameness has the capability to result in increased trim loss and decreased saleable product (NCBA, 2007) as well as negative effects on consumers' perception of animal welfare. Allen et al. (2009) concluded that after removing the physiological stress of lactation and the physical stress of walking to the milking parlor several times daily, preslaughter feeding for 90 d improved LS by reducing or removing lameness problems. In agreement with these findings, our data showed that LS decreased (less lameness) over time on feed, although the differences were not significant. Although BCS was unaffected in this study, Allen et al. (2009) and Schnell et al. (1997) both report increases in BCS after 90 and 28 d on feed, respectively, for market dairy cows. Cattle producers recognize the significance of external fatness, or body

condition, on cowherd fertility, productivity, and profitability (Dziuk and Bellows, 1983; Richards et al., 1986). Apple et al. (1999) reported that cows with a BCS of 6 (on a scale of 1-9) have the greatest potential to maximize total lean product yields and for monetary returns.

For ultrasonic carcass measurements over the course of the study, there was no treatment effect on ribeye ratio for the last 23 d of the study; however, there was a treatment effect for REA. While both CT and ZH-fed cows increased in REA over the course of the feeding, ZH-fed cows increased at a faster rate than CT cows. During the last 23 d of feeding, ZH-fed cows increased REA by 8.2 cm^2, whereas the CT cows only increased REA by 3.2 cm^2 ($P < 0.01$). Graphical representation for REA and ribeye ratio is presented in **Figure 3.1**. At the end of the trial, fatness of CT cows (BF and IMF) appeared to be increasing compared to ZH-fed cows and these differences may have become more significant with a longer feeding period or longer ZH supplementation. Graphical representation of BF and IMF during the study is presented in **Figure 3.2**.

Carcass Characteristics

Carcass data, including yield and quality factors, color, and pHu, are included in **Table 3.3**. Comparatively, ZH-fed cows had higher ($P = 0.01$) dressing percentages, increased ($P < 0.01$) REA, which ultimately led to improved ($P = 0.02$) yield grades when compared to CT cows. These findings are comparable to other reports of ZH effects on dressing percentages and REA in finishing steers (Avendano-Reyes et al., 2006; Moloney et al., 1990; Elam et al., 2009). In contrast, the findings in this study are the first for theses effects in market cows. Neill et al. (2009) reported no ZH effects on yield determining traits in market beef cows; similarly, when evaluating the effects of RAC supplementation in cows, there have been no reported treatment effects on HCW, DP, or REA (Holmer et al., 2005; Dijkhuis et al, 2008; Allen et al., 2009). The

improvements seen in this study on yield determining traits are substantial. Increases in DP of 2.6% theoretically indicate that a 600 kg cow could yield a 15 kg heavier carcass, which could possibly lead to improved profits if these cows were marketed on a value-based system, rather than traditional BW basis (Allen et al., 2009). Increased REA appears to be a direct response to β-AA induced protein synthesis and associated fiber diameter increases (Gonzalez et al., 2007). Yield grade was greatly improved by ZH supplementation in this study, primarily a result of increases in REA. Though not significant, ZH-fed cows had less KPH and adjusted BF when compared to CT cows, which also contributed to the reductions in YG for ZH-fed cows.

There was no treatment effect for any of the quality factors measured in this study. Supplementation of ZH had no effect on maturity, marbling score, fat and lean color scores, or pHu. The findings for lean color are consistent with other studies involving β-AA in finishing steers (Avendano-Reyes et al., 2006; Elam et al., 2009) and market cows (Dijkhuis et al., 2006; Neill et al., 2009; Allen et al., 2009); although preslaughter feeding has shown to improve lean color scores when compared to non-fed cows (Boleman et al., 1996; Allen et al., 2009).

Fat color is an increasingly important trait of consumer interest, and packing plants are beginning to offer a premium for cow carcasses with white fat(NCBA, 2007). Over time, as cows graze, β-carotene accumulates in the subcutaneous fat causing a yellow, undesirable color. There was no ZH effect on fat color in this study; however, others have reported that preslaughter feeding of a concentrate diet to market cows can improve fat color (Stelzleni et al., 2007; Allen et al., 2009). The lack of ZH effects on MS in this study contradict those of Elam et al. (2009) who reported that ZH feeding lowered MS for steers; however, our findings are similar to those of Neill et al. (2009) who reported no treatment effects of ZH on market cow MS.

Though not significant, pHu tended (P = 0.09) to be higher for carcasses from ZH-fed cows than those from CT cows, although the increase did not appear to impact lean color scores. Increased pH could have potential benefits to further processors who desire higher pH meat for better product stability, color, and water holding capacity.

Carcass Yields

Carcass cutout weights and percentages of cold side weight (CSW) are reported in **Tables 3.4** (forequarter) and **3.5** (hindquarter). Supplementation of market dairy cows with ZH in this study had significant effects on carcass yields. Weights for the shoulder tender, arm roast, shoulder center, brisket flat, tenderloin, cap off top round, eye round, knuckle, peeled knuckle, and tip center were greater (P < 0.05) for carcasses from ZH-fed cows than carcasses from CT cows; and weights of the whole brisket, rib roll, strip loin, top butt, primal round, top round, and tip side tended (P < 0.10) to be higher for carcasses from ZH-fed cows than carcasses from CT cows. In total, ZH supplementation resulted in nearly 11 kg more primal weight and 5.5 kg more trimmed subprimal weight compared to CT. As a percentage of CSW, shoulder tender, shoulder center, cap-off top round, eye round, and total subprimal percentages were higher (P < 0.05) for carcasses from ZH-fed cows than those from CT cows; and ZH feeding tended (P < 0.10) to increase the percentages for shoulder top, brisket flat, rib roll, tenderloin, boneless strip loin, top round, and total primals compared to CT cows. These findings are similar to those of Boler et al. (2009) who reported that ZH significantly increased subprimal weights and cutting yields in the round, loin/flank, rib/plate, and chuck of calf-fed Holstein steers when fed for at least 20 d prior to slaughter. Neill et al. (2009) also reported increases in subprimal weights for cull beef cows fed ZH for 34 days, however, Allen et al. (2009) reported no changes in strip loin, inside round, trim, and cutout weights market dairy cows supplemented with RAC.

Increased yields in this study appear to be associated primarily with the increased muscling noted for ZH-fed dairy cows. In terms of value, the added weight of the ZH carcasses resulted in a $42.34 advantage over CT carcasses. After fabrication, the subprimals of ZH carcasses were worth an additional $42.84 compared to CT. When expressed as a percent of CSW, subprimal yields from ZH carcasses were typically greater than those from CT carcasses. This became more evident as bone and fat were trimmed from the subprimal and the weight represented muscle alone. This is consistent with the mode of action for ZH, which increases muscle protein synthesis and decreases muscle protein degradation, causing significant protein accretion.

IMPLICATIONS

In conclusion, ZH feeding appears to have substantial benefits for the market dairy cow industry. Zilpaterol added significant value to the slaughter cow carcasses in this study, through increases in muscle weight and cut yields. This occurred in the absence of any effects on meat quality. To better understand the potential benefits of market cow feeding, further research needs to be done to compare non-fed cows to those that have been on short-term feeding regimens that may include ZH. Finally, in order for slaughter cow feeding with ZH supplementation to be implemented by the industry, ZH-fed cows will have to be marketed in a value-based system that allows the feeder to glean the value associated with the added carcass weight and muscling.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the technical support of Mike Mathis, Ryan Crowe, and Gina McKinney, University of Georgia, Animal and Dairy Science Department (Athens, GA).

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Table 3.1. Diet for CT and ZH cows, % DM basis

	Treatment[1]	
Ingredient	CT	ZH
Peanut Hulls	39.54	39.54
Soybean Hulls	19.97	19.97
Corn Gluten Feed	19.78	19.78
Corn – dry grind	18.60	18.60
Wheat Middlings	2.12	2.02
Zilpaterol HCl	-	0.10

[1]CT = fed for 42 d; ZH = fed 42 d with Zilmax (7.5 ppm; Intervet Schering-Plough Animal Health, Millsboro, DE) from d 19-39 followed by a 3 d withdrawal.

Table 3.2. Least squares means and SEM for treatment and time on feed main effects in market dairy cow BCS, LS, BW, and growth performance.

	Treatment[1]			
Trait	CT	ZH	SEM	*P*-value
BCS[2]				
D 0	3.1	3.1	0.15	0.89
D 19	3.1	3.3	0.15	0.30
D 42	3.1	3.1	0.15	0.74
LS[3]				
D 0	1.9	1.9	0.22	0.88
D 19	2.0	1.9	0.22	0.91
D 42	1.6	1.6	0.22	0.98
BW				
D 0	617.4	632.8	21.80	0.62
D 19	629.6	657.4	21.80	0.37
D 42	645.8	659.0	21.80	0.67
Performance				
ADG, D 20-42, kg/d	0.72	0.27	0.25	0.24
ADG, Overall, kg/d	0.83	0.62	0.20	0.46
G:F, D 20-42, kg/kg	0.050	0.025	0.160	0.27
G:F, Overall, kg/kg	0.063	0.044	0.018	0.49
DMI, D 20-42, kg/d	15.1	13.7	0.90	0.30
DMI, Overall, kg/d	12.9	13.0	0.68	0.86

[1]CT = fed for 42 d; ZH = fed 42 d with Zilmax (7.5 ppm; Intervet Schering-Plough Animal Health, Millsboro, DE) from d 19-39 followed by a 3 d withdrawal.
[2]BCS scale: 1 = emaciated; 5 = extremely overconditioned (Wildman et al., 1982)
[3]Locomotion score scale: 1 = no signs of lameness; 5 = severely lame (Zinpro Corporation, Eden Prairie, MN)

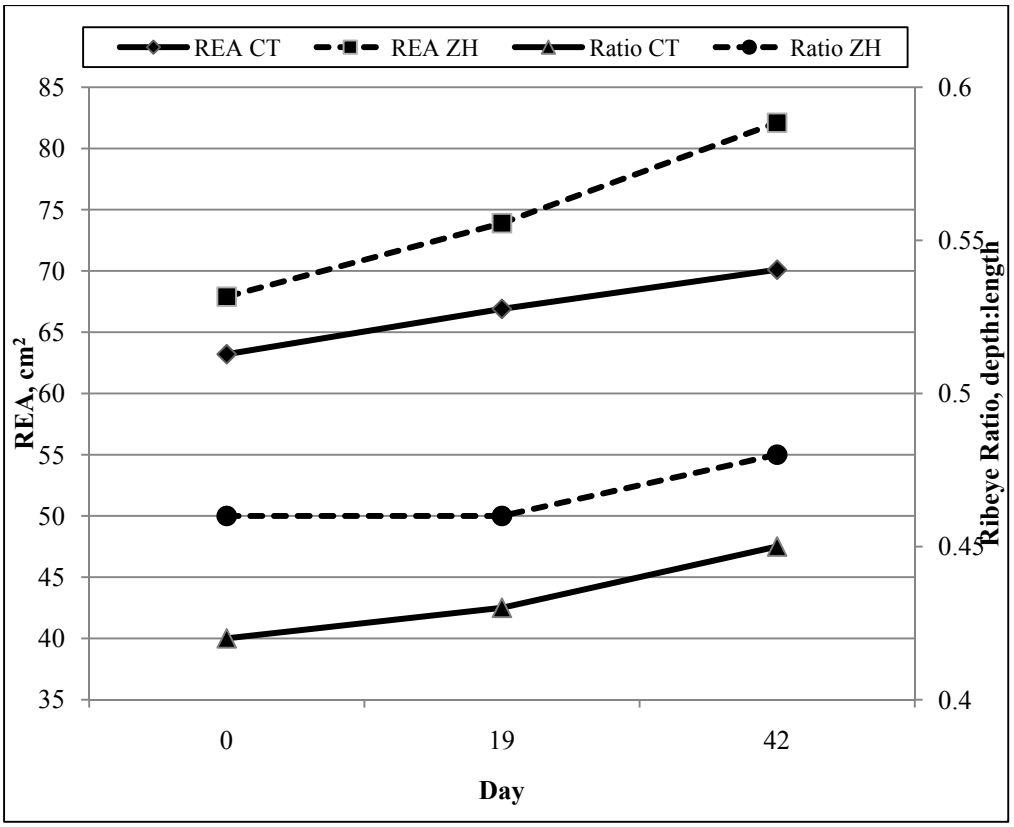

Figure 3.1. Ultrasound ribeye area (REA) and ribeye ratio (depth:length) by treatment and time on feed.

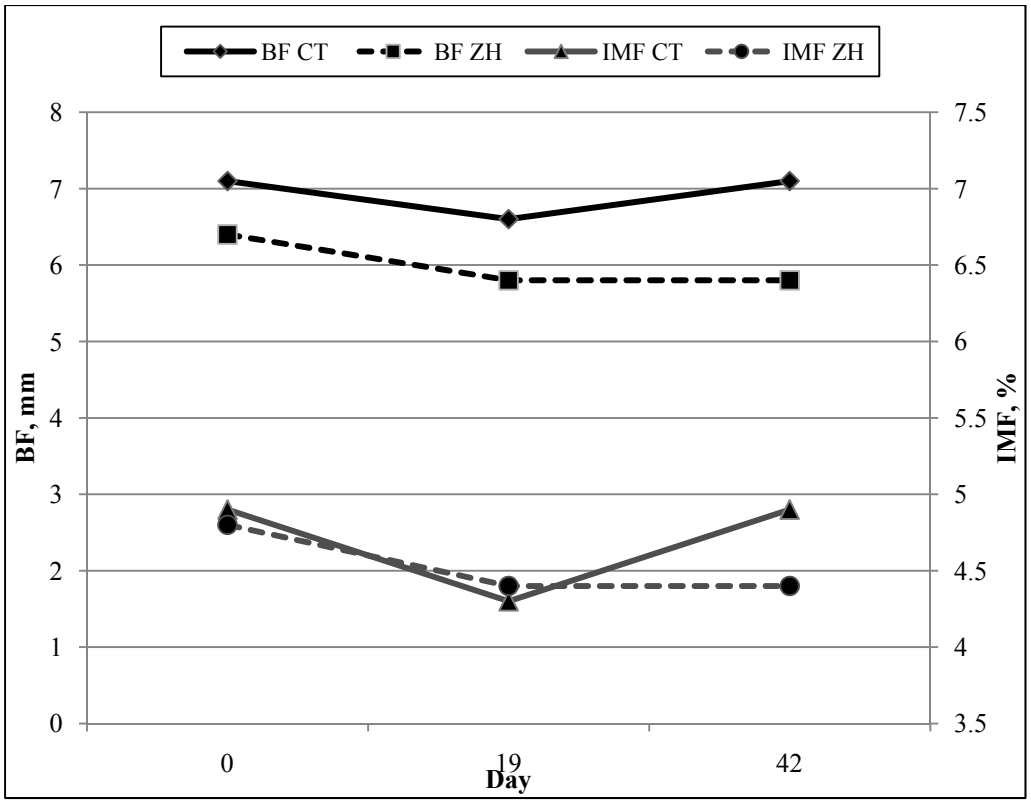

Figure 3.2. Ultrasound 12th rib backfat (BF) and intramuscular fat (IMF) percentage by treatment and time on feed.

Table 3.3. Least squares means and SEM for treatment effects in market dairy cow carcass yield and quality characteristics.

	Treatment[1]			
Trait	CT	ZH	SEM	*P*-value
BW, kg	614.9	622.6	21.03	0.80
HCW, kg	341.3	361.5	14.24	0.32
Dressing Percentage, %	55.3	57.9	0.72	0.01
Adj. BF, mm	6.91	5.41	0.93	0.26
REA, sq. cm.	69.2	80.7	2.44	< 0.01
KPH, % of HCW	2.1	1.9	0.18	0.49
Lean Maturity[2]	469	442	24.43	0.43
Bone Maturity[2]	463	491	27.27	0.47
Overall Maturity[2]	470	470	23.40	0.97
Marbling Score[3]	575	583	33.97	0.87
YG	3.0	2.4	0.17	0.02
QG[4]	5.9	5.0	0.84	0.42
Fat Color				
L*	75.34	74.99	0.98	0.80
a*	8.01	8.66	0.75	0.55
b*	25.57	26.94	1.22	0.43
Subjective[5]	1.8	2.0	0.31	0.74
Lean Color				
L*	27.22	29.34	0.94	0.13
a*	26.15	24.68	0.98	0.29
b*	22.30	20.16	1.00	0.14
IMF, %	4.47	4.89	0.64	0.65
pHu, 48h	5.47	5.58	0.05	0.09

[1]CT = fed for 42 d; ZH = fed 42 d with Zilmax (7.5 ppm; Intervet Schering-Plough Animal Health, Millsboro, DE) from d 19-39 followed by a 3 d withdrawal.
[2]Maturity classifications: $A^0 = 100$; $B^0 = 200$; $C^0 = 300$; $D^0 = 400$; $E^0 = 500$
[3]Marbling score classifications: $Slight^0 = 400$; $Small^0 = 500$, etc.
[4]Quality Grade codes: 5 = high Utility; 6 = low Commercial
[5]Fat color scale: 1= bleached white; 5 = canary yellow

Table 3.4. Least squares means and SEM for treatment effects in market dairy cow fabrication data for primal, subprimal and selected added-value cuts from the forequarter.

	Weight, kg				% of CSW[1]			
	Treatment[2]				Treatment[2]			
	CT	ZH	SEM	*P*-value	CT	ZH	SEM	*P*-value
CSW	168.50	177.80	7.03	0.36	-	-	-	-
Chuck	59.20	62.97	2.26	0.25	35.27	35.50	0.35	0.64
Shoulder Clod	9.12	9.88	0.41	0.20	5.42	5.55	0.07	0.24
Top Blade	2.30	2.43	0.09	0.34	1.37	1.37	0.02	0.97
Shoulder Tender	0.36[a]	0.43[b]	0.01	< 0.01	0.22[a]	0.24[b]	0.00	0.04
Arm Roast	4.06[a]	4.60[b]	0.19	0.05	2.43	2.59	0.06	0.11
Shoulder Top	1.00	0.94	0.05	0.36	0.61[y]	0.53[z]	0.03	0.07
Shoulder Center	1.79[a]	2.15[b]	0.09	0.01	1.09[a]	1.21[b]	0.04	0.05
Chuck Roll	6.46	7.11	0.31	0.15	3.84	4.00	0.08	0.18
Brisket	4.09[y]	4.64[z]	0.22	0.09	2.44	2.61	0.09	0.19
Brisket Flat	1.96[a]	2.28[b]	0.10	0.04	1.17	1.28	0.04	0.08
Rib	10.09	10.86	0.42	0.20	6.03	6.10	0.09	0.61
Rib Roll	4.03[y]	4.53[z]	0.19	0.07	2.41[y]	2.54[z]	0.05	0.07

[1]CSW = cold side weight

[2]CT = fed for 42 d; ZH = fed 42 d with Zilmax (7.5 ppm; Intervet Schering-Plough Animal Health, Millsboro, DE) from d 19-39 followed by a 3 d withdrawal.

[a, b]Means within row within subset with different superscripts differ (P < 0.05)

[y, z]Means within row within subset with different superscripts differ (P < 0.10)

Table 3.5. Least squares means and SEM for treatment effects in market dairy cow fabrication data for primal, subprimal, and selected added-value cuts from the hindquarter and total primal and subprimal cuts from whole side.

	Weight, kg				% of CSW[1]			
	Treatment[2]				Treatment[2]			
	CT	ZH	SEM	*P*-value	CT	ZH	SEM	*P*-value
Flank	9.30	9.80	0.63	0.58	5.44	5.45	0.20	0.97
Flank Steak	0.86	0.92	0.04	0.30	0.52	0.52	0.02	0.82
Loin	25.52	27.54	1.05	0.18	15.16	15.55	0.22	0.22
Tenderloin	2.44[a]	2.87[b]	0.10	< 0.01	1.47[y]	1.62[z]	0.09	0.07
Short Loin	6.44	6.76	0.31	0.47	3.80	3.80	0.09	0.96
Strip Loin	4.23[y]	4.77[z]	0.20	0.06	2.51[y]	2.69[z]	0.07	0.06
Sirloin	10.19	10.69	0.43	0.42	6.11	6.03	0.18	0.76
Top Butt	5.02[y]	5.57[z]	0.21	0.06	3.00	3.14	0.08	0.23
Round	38.72[y]	42.94[z]	1.55	0.06	23.19	24.19	0.40	0.12
Top Round	9.14[y]	10.15[z]	0.36	0.06	5.46[y]	5.72[z]	0.10	0.08
Cap off Top Round	5.56[a]	6.34[b]	0.21	0.01	3.35[a]	3.62[b]	0.09	0.05
Gooseneck Round	11.22	12.21	0.54	0.21	6.67	6.84	0.11	0.30
Eye Round	2.12[a]	2.54[b]	0.09	< 0.01	1.27[a]	1.43[b]	0.04	< 0.01
Flat	5.58	6.14	0.25	0.12	3.34	3.44	0.07	0.29
Knuckle	4.99[a]	5.69[b]	0.24	0.04	2.99	3.22	0.12	0.19
Peeled Knuckle	4.54[a]	5.25[b]	0.24	0.04	2.71	2.97	0.13	0.17
Tip Center	1.48[a]	1.78[b]	0.09	0.03	0.89	1.00	0.05	0.17
Tip Side	1.80[y]	2.06[z]	0.10	0.06	1.08	1.17	0.05	0.24
Primal Total	133.52	144.30	5.05	0.14	79.65[y]	81.34[z]	0.64	0.07
Subprimal Total	66.38	71.82	2.49	0.13	39.15[a]	40.32[b]	0.34	0.02

[1]CSW = cold side weight

[2]CT = fed for 42 d; ZH = fed 42 d with Zilmax (7.5 ppm; Intervet Schering-Plough Animal Health, Millsboro, DE) from d 19-39 followed by a 3 d withdrawal.

[a, b]Means within row within subset with different superscripts differ (P < 0.05)

[y, z]Means within row within subset with different superscripts differ (P < 0.10)

Chapter 4

EFFECTS OF ZILMAX FEEDING ON TENDERNESS OF SELECTED ADDED-VALUE STEAKS AND SUBCUTANEOUS FAT QUALITY FROM MARKET DAIRY COWS

Lowe, B. K., A. M. Stelzleni, J. A. Safko, R. O. McKeith, J. R. Segars, R. M. Pitzer, R. L. Stewart, M. A. Froetschel, and T. D. Pringle. To be submitted to Journal of Animal Science

ABSTRACT

Thirty-four cull dairy cows were used in this study to evaluate the effects of preslaughter feeding with or without zilpaterol HCl (ZH; Zilmax®, Intervet Schering-Plough Animal Health, Millsboro, DE) supplementation at 7.5 ppm on tenderness and fat quality. For tenderness, *m. infraspinatus* (FI), m. longissimus dorsi (LD), m. gluteus medius (GM), and *m. rectus femoris* (RF) were excised and aged. For fat quality, a sample of subcutaneous (s. c.) adipose tissue was removed from carcasses and lipids extracted and transmethylated to determine fatty acid percentages and conjugated linoleic acid (CLA) content. Only effect of treatment on drip loss occurred in the LD steaks from cows treated with ZH which caused an increase ($P = 0.02$) in drip loss. Aging resulted in decreases ($P < 0.05$) in cook loss for LD and GM steaks for both treatments, and an increase ($P = 0.03$) for FI steaks with no effect ($P = 0.28$) on RF cook loss. For Warner-Bratzler shear force (WBSF) determination, LD steaks from ZH treated cows had higher ($P < 0.01$; i.e. less tender) values when compared to controls (CT); steaks from CT cows became more ($P < 0.05$) tender after 14 d of aging compared to 21 d for steaks from ZH cows. Steaks from ZH cows tended ($P = 0.07$) to have higher slice shear force (SSF) values when compared to CT; SSF of LD steaks from CT cows decreased ($P < 0.05$) after 7 d, whereas steaks from ZH cows decreased ($P < 0.05$) after 21 d. For GM steaks, ZH caused an increase ($P < 0.01$) in SSF; ZH steaks became more tender ($P < 0.05$) after 21 d and CT steaks after 28 d. For FI steaks, no difference ($P = 0.86$) between treatments was found; SSF decreased ($P < 0.01$) as aging time increased; ZH steaks became more ($P < 0.05$) tender after aging, whereas there was no difference ($P > 0.05$) in CT steaks after aging. There were no differences ($P > 0.05$) in evaluating treatment, age, or treatment × age interaction for RF steaks and SSF. For fatty acid analysis, SQ tissue from CT cows had a higher ($P = 0.02$) percentage of C14:0, whereas ZH

cows had a higher (P = 0.03) percentage of C18:1, *cis*-9. Percentage of PUFA in CT cows tended (P = 0.09) to be higher when compared to ZH-fed cows; there were no differences (P = 0.60) for SFA and MUFA across treatment.

Key words: zilpaterol, market cow, tenderness, fat quality

INTRODUCTION

Zilpaterol hydrochloride (ZH) is a member of a class of synthetic growth enhancers known as β2-adrenergic agonists (β-AA). Although responses to β-AA vary, the most consistent biological effect is an increase in skeletal muscle protein accretion, which has been documented to cause hypertrophic increases in muscle fiber diameter (Gonzalez et al., 2007). This increase in fiber diameter has been associated with reduced tenderness in β-AA-fed cattle (Avendano-Reyes et al., 2006). It is supposed that the associated with β-AA mode of action (increased protein synthesis and decreased protein degradation) also reduces postmortem proteolysis, or aging, of muscles from β-AA treated animals, and in turn, reduces tenderness (Pringle et al., 1993). However, little is known about the effects of β-AA feeding on beef tenderness from market dairy cows.

Advances in fabrication of beef carcasses have led to increased utilization of the chuck and round from cow carcasses. These new "Beef Value Cuts" have opened new avenues for product from slaughter cows to move into the beef market. Today's consumer continues to demand convenience and quality in meat products. In the past, the primary muscles used for intact, whole-muscle beef were the middle meats (i.e., rib and loin). With the introduction of the Beef Value Cuts, new cuts of beef like the flat iron, out of the chuck, and the tip center, out of the round, have found there way into dining rooms and restaurants around the country. These new concepts have made beef more interesting to the consumer and most importantly, increased the value of cuts from the chuck and round.

Conjugated linoleic acid (CLA) is a collective term used to describe one or more positional and geometric isomers of linoleic acid (*cis*-9, *cis*-12-octadecadienoic acid; Corriher et al., 2009). Enhancing the content of the *cis*-9, *trans*-11 isomer of CLA has acquired attention in

the beef industry because of its antiatherogenic effects (Scollan et al., 2006). Milk and beef represent the major sources of CLA in the human diet (Ritzenthaler et al., 2001). Although CLA are produced in the rumen by incomplete biohydrogenation of dietary C18:2n-6, CLA is also synthesized in adipose tissue and in the mammary gland by desaturation of C18:1 *trans*-11 (Griinari et al., 2000). The effect of β-AA feeding on fatty acid composition of beef fat has not been well documented. Thus, this experiment was conducted to evaluate the cooking properties and tenderness of selected added-value cuts and s.c. fat quality in market dairy cows fed ZH.

MATERIALS AND METHODS

All animal use and handling techniques described herein were approved by the University of Georgia Animal Care and Use Committee.

Cattle and Dietary Treatments

Thirty-four cull dairy cows, of predominantly Holstein breeding, were used in this study to investigate the effects of zilpaterol hydrochloride (ZH) supplementation on tenderness of selected added-value steaks and s.c. fat quality. Cows were acquired from local dairies in the northeast Georgia and southwest South Carolina. Upon arrival at The University of Georgia Wilkins Beef Unit in Rayle, GA, cows were treated with an orally-administered anthelmintic; a 7-way clostridia vaccine; a broad spectrum vaccine (IBR, PI3, BVD, BRSV, and Lepto); weighed; and ear tagged. Cows were held on pasture (native Bermuda) during the quarantine period of 21 d. During this period, cows were observed for any issues that might hinder their performance in the study, such as lameness or health problems.

Cows that were deemed acceptable for the study were stratified by weight and randomly assigned to one of two treatments: 1) a concentrate fed diet for 42 d (CT), and 2) a concentrate fed diet for 42 d with supplementation of ZH (Zilmax®, Intervet Schering-Plough, Millsboro,

DE) from d 19-39 followed by a 3 d withdrawal. Cows were implanted in the left ear with Revalor-200 (200 mg of trenbolone acetate and 20 mg of estradiol; Intervet Schering-Plough, Millsboro, DE) on d -7. Cows were fed a diet made up of regionally available feedstuffs (**Table 3.1**) where the overall diet contained 58.5% TDN and 12.7% CP. Zilmax was received as a pelleted pre-mix that contained 320 g Zilpaterol HCl / ton of pelleted wheat middlings. The pre-mix was added to the diet at the rate of 2.12%, which resulted in 7.5 ppm of active ingredient. The feed and pre-mix was mixed in data ranger (5 min) and fed in a Calan gate system. Cows not receiving ZH received additional pelleted wheat middlings at the rate of 2.12% mixed into the diet. Feed analysis showed that ZH were within acceptable levels for ZH diet and that no ZH was present in the CT diet. At the conclusion of the feeding period, cows were transferred to the University of Georgia Meat Science and Technology Center where they were held overnight with free access to water.

Harvest and Sample Collection

Cows were humanely slaughtered under federal inspection and after a 48 h chill (-2°C) left sides of carcasses were separated into primal cuts by trained plant personnel. Muscles of interest were then excised from the chuck, loin, and round. Muscles excised included *m. Infraspinatus* from the chuck, which was further fabricated by removing the bipennae connective tissue to yield the "flat iron" (FI) added-value cut; *m. Longissimus dorsi* (LD) and *m. Gluteus medius* (GM) from the loin; and *m. Rectus femoris* from the round (RF). For slice shear force (SSF) determination, FI steaks (n = 2; 2.54-cm thick) were cut and randomly assigned to aging times of 14 or 21 d; GM steaks (n = 4; 2.54-cm thick) were cut and randomly assigned to aging times of 3, 14, 21, or 28 d; RF steaks (n = 2; 2.54-cm thick) were cut and randomly assigned to aging times of 14 or 21 d; and LD steaks (n = 5; 2.54-cm thick) were cut and randomly assigned

to aging times of 3, 7, 14, 21, or 28 d. Additionally, five LD steaks (2.54-cm thick) were cut and randomly assigned to aging times of 3, 7, 14, 21, or 28 d for determination of Warner-Bratzler shear force (WBSF). Samples were vacuum-packaged, aged (4°C) for assigned times, and frozen (-29°C). On the right sides of carcasses, a s.c. adipose tissue sample (2 g) was obtained from the area adjacent to the 12th rib and ventral to the longissimus muscle for fatty-acid analysis.

Slice Shear Force Determination

For SSF determination in FI, GM, RF, and LD steaks, the previously described thawing and cooking procedures for WBSF were used. Methods for SSF determination were obtained from Shackelford et al. (1999b), with modifications. After cooked weights were recorded, two 1-cm by 5-cm slices were cut parallel to the muscle fiber orientation, using a 45° slice box and a double bladed knife. Two slices were taken from FI, LD, and RF steaks; whereas, three were taken from GM steaks (one distal, one medial, and one proximal). Slices were sheared once perpendicular to the fiber orientation using an Instron Universal Testing Machine (Model 3365, Instron Corporation, Canton, MA) equipped with a flattened, blunt blade (1.02 mm thick) and a 500 N load cell with a crosshead speed of 500 mm/min. Slice shear force was reported in kgf as the average of the measured slices.

Warner-Bratzler Shear Force Determination

Steaks were weighed prior to thawing and allowed to thaw for 18 h at 4°C. After thawing, steaks were blotted dry and thaw weights recorded to determine drip loss; drip loss was determined using the following equation: ((frozen – thawed) / frozen) × 100%. Steaks were then cooked on preheated broilers (model 450N Open-Hearth Broiler, Farberware, Bronx, NY) to an internal temperature of 71°C (AMSA, 1995). Internal temperature was monitored by copper-constantan thermocouples (Omega Engineering, Stamford, CT) placed in the approximate

geometric center of each steak. Once internal temperature was reached, steaks were weighed and cook loss determined using the following formula: ((thawed – cooked) / thawed) × 100%. After collecting cooked weight, a 1-cm slice from the distal end was removed and degree of doneness (DOD) was evaluated on a 6-point scale (1 = very rare, 6 = well done; AMSA, 1995). Steaks were cooled for 12 h at 4°C and 6 cores (1.27-cm diameter) were taken parallel to the longitudinal orientation of the muscle fibers. Cores were sheared once perpendicular to the longitudinal orientation of the muscle fibers using an Instron Universal Testing machine (Model 3365, Instron Corp., Canton, MA) equipped with a Warner-Bratzler shear head and a 500 N load cell with a crosshead speed of 250 mm/min. Warner-Bratzler shear force was reported in kgf as the average of 6 core measurements.

Fatty Acid Analysis

For lipid extraction, s.c. adipose tissue samples were frozen in liquid nitrogen and pulverized. Total lipids were extracted in duplicate (0.4 g per sample) according to the chloroform/methanol procedure of Folch et al. (1957). The s.c. extracts, containing approximately 2 mg of total lipids, based on the calculated percentage of lipids on a wet tissue basis, were transmethylated (Park and Goins, 1994). Fatty acid methyl esters were analyzed using an HP6850 gas chromatograph (Hewlett-Packard, San Fernando, CA) equipped with an HP7673A automatic sampler (Hewlett-Packard). Separations were accomplished using a 100-m Sp2560 capillary column (0.25 mm i.d. and 0.20-µm film thickness; Supelco, Bellefonte, PA) according to the method of Duckett et al. (2002). Column oven temperature increased from 150 to 160°C at 1°C per min, from 160 to 167°C at 0.2°C per min, from 167 to 225°C at 1.5°C per min, and was then held at 225°C for 16 min. The injector and detector temperatures were maintained at 250°C. Sample injection volume was 1 µL. Hydrogen was the carrier gas at a

flow rate of 1 mL/min. Individual fatty acids were identified by comparisons of retention times with standards (Sigma, St. Louis, MO; Supelco; Matreya, Pleasant Gap, PA). The fatty acids were quantified by incorporating an internal standard, methyl heptacosanoic acid (C27:0), into each sample during methylation and were expressed as % of total fatty acids.

Statistical Analysis

Statistical analyses were conducted using the GLM procedure (SAS Inst. Inc., Cary, NC). Animal was the experimental unit for all variables measured in the trial. Treatment means were generated and partitioned using the LSMEANS and PDIFF options. Thaw loss, cook loss, and tenderness were evaluated as repeated measures over time, with the main effects of treatment, aging time, and their interaction. For tenderness analysis, degree of doneness was used as a covariate. Correlations were conducted using the CORR procedure in SAS and regressions conducted using the REG procedure. Data for fatty acids were analyzed using ANOVA, with treatment, replicate and their interaction in the model and LSMEANS were generated. Differences were deemed significant at $P < 0.05$ and tendencies at $P < 0.10$.

RESULTS AND DISCUSSION

Cooking Properties and Muscle Tenderness

Drip loss is reported in **Table 4.1**. The only treatment effect on drip loss was seen in LD steaks, where ZH steaks had increased (P = 0.02) drip loss when compared to control steaks. There also was an age effect on drip loss, drip loss for LD steaks decreased (P < 0.05) across aging time and increased (P = 0.03) in FI steaks. In general, drip loss was lowest after 21 d of aging but not different after 3, 14, or 28 d of aging. Cook loss means (**Table 4.2**) showed no ZH effect on cook loss. Across aging times, LD steaks showed lower (P < 0.01) cook loss as aging time increased; however, cook loss was not affected by aging in other muscles.

Tenderness data is reported in **Table 4.3**. For SSF of LD steaks, steaks from ZH-fed cows tended ($P = 0.07$) to have higher SSF values (i. e. less tender) than steaks from control cows. Aging caused a decrease ($P < 0.01$) in SSF similar to the change noted in WBSF, specifically, steaks aged 14 d or longer were more tender ($P < 0.05$) than steaks aged 3 or 7 d. Steaks from control cows decreased ($P < 0.05$) in SSF after 14 d of aging, compared to steaks from ZH-fed cows that required 21 d of aging in order to show significant tenderization. For WBSF, steaks from ZH-fed cows had higher ($P < 0.01$) WBSF values (i. e. less tender) when compared to steaks from controls. As expected, aging of LD steaks decreased ($P < 0.05$) WBSF values, with significant changes occurring from 3 to 14 d, and from 14 d to 21 d. Within a treatment, control steaks became more tender ($P < 0.05$) after 14 d of aging, whereas ZH steaks did not respond to aging until after 21 d of aging.

Slice shear force of GM steaks from ZH-fed cows was higher ($P < 0.01$) when compared to GM steaks from controls. Additionally, SSF decreased ($P < 0.01$) from 3 d to 14 d of aging; however, additional aging did not improve SSF measures in these market dairy cows. In general, LD and GM steaks from control cows neared their maximum tenderness after 14 d of aging, while steaks from ZH-fed cows required an additional 7 days of aging to reach their maximum tenderness levels. For FI steaks, ZH feeding did not impact ($P = 0.86$) however, steaks decreased ($P < 0.01$) is SSF from d 14 to d 21. There were no differences ($P > 0.05$) in SSF across treatment or aging for RF steaks.

Tenderness is considered very critical when evaluating eating experiences of fresh meat. Many factors influence tenderness, such as, diet, processing methods, and postmortem proteolysis, or aging. Supplementation of β-AA has been shown to increase WBSF (up to 300%), and adversely affect consumer sensory scores (Hilton et al., 2009; Leheska et al., 2009).

Clenbuterol supplementation has been shown to increase WBSF of beef steers and heifers from 14% to 113% when fed 35 to 50 d (Miller et al., 1988; Schiavetta et al., 1990). It has also been reported that $L_{644, 969}$ (β2-AA) increases WBSF in lambs (Pringle et al., 1993). Schroeder et al. (2003) reported a 12% increase in WBSF when beef steers were supplemented with ractopamine hydrochloride (RAC). Brooks et al. (2009) reported that ZH feeding for at least 20 d increased WBSF of longissimus, gluteus medius, and triceps brachii steaks. However, there was no treatment × aging interaction. It is understood that postmortem proteolysis causes tenderness to increase due to protein degradation via the calpain system. Strydom and Nel (1996) reported a decrease in shear force when steaks from ZH treated cattle were aged from 7 to 14 d. Buys and Strydom (2000) observed a 10% improvement in shear force when steaks from ZH animals were aged 3 to 10 d postmortem. In addition, Hilton et al. (2009) reported WBSF significantly decreased from 7 to 21 d postmortem among steaks from animals supplemented with ZH for 30 d.

In reference to cull cow feeding, Boleman et al. (1996) reported that preslaughter concentrate feeding of cull cows for 56 d resulted in decreased WBSF. Dijkhuis et al. (2008) reported varying results when measuring the effects of different levels of RAC supplementation on tenderness in various muscles from cull cows; however, it was reported that infraspinatus steaks from RAC supplemented cows had higher WBSF values than those from control cows, which contradicts the findings in this study. It has been reported that RAC supplementation in cows causes an increase in muscle fiber diameter (Gonzalez et al., 2007), and that this increased fiber diameter is inversely related to tenderness. Baxa et al. (2009) also reported that β-AA supplementation causes a shift from the more tender type IIA muscle fibers to the less tender type IIX. Therefore, cows supplemented with ZH should have decreased tenderness due to

increased fiber diameter caused by increased protein synthesis; and decreased responses to aging due to decreased postmortem proteolysis from inhibited calpain action.

Along with comparisons of ZH supplementation to market dairy cows and its effects on tenderness, this study also evaluated the correlation of WBSF to SSF in LD steaks from these market dairy cows. Beef WBSF is a highly repeatable (0.53 – 0.86) measurement of tenderness when protocols are executed properly (Wheeler et al., 1994, 1996, 1997). Wheeler et al. (1994, 1996, 1997) identified several sources of error that contribute to faulty shear force assessment; therefore, a simplified technique was developed for on-line assessment of tenderness by Shackelford et al. (1999a), referred to as slice shear force, which was reportedly more accurate and repeatable (0.89) than WBSF. A graphical comparison of treatment and aging effects on WBSF and SSF is presented in **Figure 4.1**. Correlation with regression can be found in **Figure 4.2**.

It is important to consider source when evaluating tenderness. The cows in this study were older dairy cows with little predictability about tenderness. Many studies that have evaluated correlations between WBSF and trained sensory panel perceived tenderness or SSF utilize fed beef from young steers and heifers (Shackelford et al., 1999b). Correlations between WBSF and SSF in LD steaks from market dairy cows in this study were comparable to those of Shackelford et al. (1999b).

Fatty Acid Composition

For fatty acid analysis, the percentage of C14:0 was higher ($P = 0.02$) in control cows than cows fed ZH (3.47 vs. 3.00), while ZH-fed cows had a higher percentage of C18:1, *cis* 9 than control cows (42.59 vs. 40.53, $P = 0.03$). Although the percentage of SFA and MUFA did not differ across treatment ($P > 0.60$), the percentage of PUFA tended to be higher ($P = 0.09$) in

the control group than the ZH-fed cows. While ZH has been shown to increase lean accretion, these data suggest that it does not greatly impact s.c. fat quality in fed Holstein cows.

IMPLICATIONS

Similar to other β-AA, ZH had a significant effect on tenderness in this study. Tenderness is still sought after in producing consumer-accepted quality beef. Although, ZH fed cows in this study produced less tender steaks, there are still further processing techniques that could be implemented to ensure a tender product. Longer aging times may also be required for product from ZH-fed cows. In this study ZH-fed cows required about 7 d longer aging than control-fed cows to reach similar levels of tenderness. As with all production systems, there has to be compromise in developing a quality product. Tenderness may have to be sacrificed at the expense of increased yields in order to increase returns. Although LD and GM steak tenderness was negatively impacted by ZH, there was not a detrimental effect on tenderness for the RF and FI steaks, indicating that ZH supplementation could possibly be an option for producers or packers looking to increase value-cut yields without compromising tenderness.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the technical support of Mike Mathis, Ryan Crowe, and Gina McKinney, University of Georgia, Animal and Dairy Science Department (Athens, GA).

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Table 4.1. Effect of zilpaterol hydrochloride (ZH) feeding and aging time on drip loss (%) in longissimus dorsi (LD), gluteus medius (GM), infraspinatus (FI), and rectus femoris (RF) steaks from market dairy cows

Main Effect	LD	GM	FI	RF
ZH[1] Inclusion level, ppm				
0	1.79[a]	3.76	0.80	1.23
7.5	2.17[b]	3.61	0.61	1.01
SEM	0.11	0.17	0.11	0.12
P-value	0.02	0.55	0.22	0.17
Aging time, d				
3	2.99[a]	4.20[a]	-	-
7	3.02[a]	-	-	-
14	2.11[b]	3.62[a]	0.53[a]	1.03
21	0.77[c]	2.83[b]	0.87[b]	1.21
28	1.00[c]	4.11[a]	-	-
SEM	0.17	0.24	0.11	0.12
P-value	< 0.01	< 0.01	0.03	0.28

[a-c] Means within column within main effect with different superscripts differ (P < 0.05)

Table 4.2. Effect of zilpaterol hydrochloride (ZH) feeding and aging time on cook loss (%) in longissimus dorsi (LD), gluteus medius (GM), infraspinatus (FI), and rectus femoris (RF) steaks from market dairy cows

Main Effect	LD	GM	FI	RF
ZH Inclusion level, ppm				
0	22.37	26.83	28.62	25.56
7.5	23.56	27.75	28.53	24.50
SEM	0.51	0.82	0.90	0.12
P-value	0.10	0.43	0.94	0.57
Aging Time, d				
3	26.50[a]	27.09	-	-
7	24.91[a]	-	-	-
14	21.10[b]	28.17	28.64	25.25
21	21.39[b]	28.50	28.52	24.81
28	20.90[b]	25.42	-	-
SEM	0.80	1.16	0.90	1.30
P-value	< 0.01	0.24	0.92	0.81

[a, b] Means within column within main effect with different superscripts differ ($P < 0.05$)

Table 4.3. Effect of zilpaterol hydrochloride (ZH) feeding and aging time on tenderness[1] in longissimus dorsi (LD), gluteus medius (GM), infraspinatus (FI), and rectus femoris (RF) steaks from market dairy cows

Main Effect	LD (WBSF)	LD (SSF)	GM (SSF)	FI (SSF)	RF (SSF)
ZH Inclusion level, ppm					
0	4.09^{a}	24.50	21.94^{a}	17.79	20.26
7.5	4.72^{b}	26.88	25.41^{b}	17.97	23.21
SEM	0.16	0.92	0.70	0.70	1.31
P-value	< 0.01	0.07	< 0.01	0.86	0.12
Aging Time, d					
3	5.37^{a}	31.17^{a}	26.64^{a}	-	-
7	5.03^{ab}	28.56^{a}	-	-	-
14	4.54^{b}	24.32^{b}	23.57^{b}	19.12^{a}	22.92
21	3.55^{c}	21.30^{b}	21.66^{b}	16.65^{b}	20.55
28	3.55^{c}	23.07^{b}	22.83^{b}	-	-
SEM	0.25	1.46	0.99	0.69	1.34
P-value	< 0.01	< 0.01	< 0.01	0.01	0.23
Treatment[2] × Aging Time					
CT					
3	5.37^{a}	31.69^{a}	24.87^{bc}	-	-
7	4.59^{ab}	27.39^{abc}	-	-	-
14	3.94^{bc}	22.45^{cde}	21.03^{cd}	18.38^{ab}	22.07
21	3.34^{c}	20.63^{de}	20.64^{cd}	17.21^{ab}	18.46
28	3.22^{c}	20.30^{e}	21.22^{d}	-	-
ZH					
3	5.36^{a}	30.66^{ab}	28.40^{a}	-	-
7	5.46^{a}	29.73^{ab}	-	-	-
14	5.15^{a}	26.19^{abcd}	26.12^{ab}	19.86^{a}	23.78
21	3.76^{bc}	21.98^{cde}	22.68^{bcd}	16.08^{b}	22.64
28	3.87^{bc}	25.85^{bcde}	24.45^{bcd}	-	-
SEM	0.36	2.08	0.13	0.98	1.86
P-value	0.51	0.58	0.75	0.19	0.51

[1]WBSF = Warner-Bratzler shear force, kgf; SSF = slice shear force, kgf

[a-e] Means within column within main effect with different superscripts differ (P < 0.05)

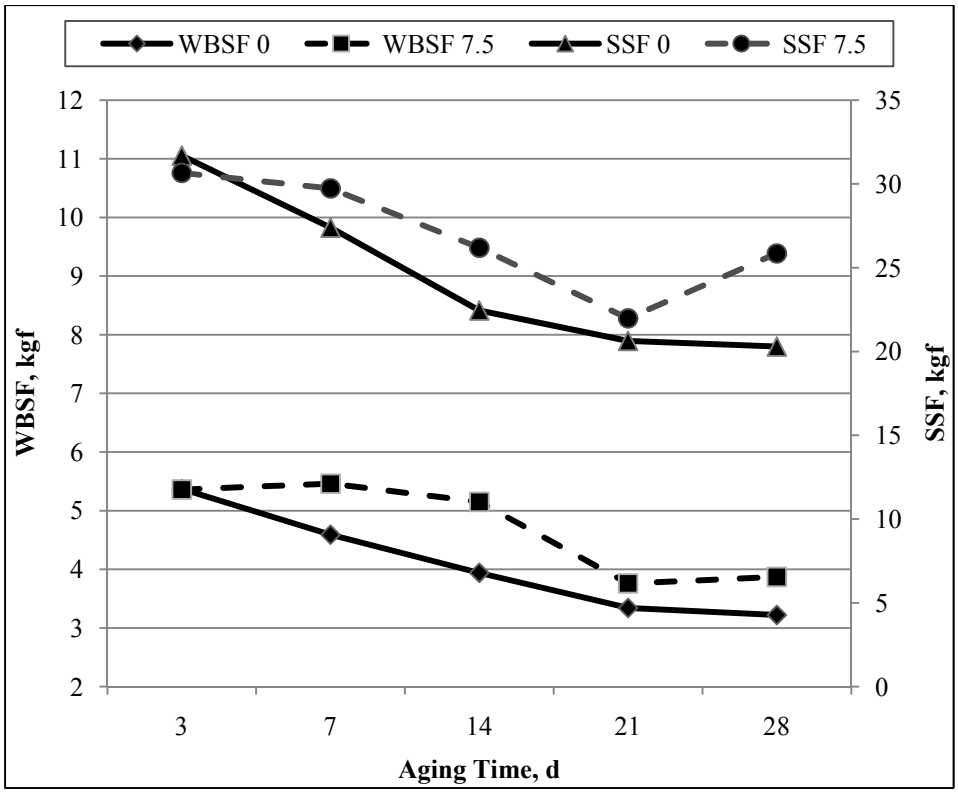

Figure 4.1. Effect of aging time on Warner-Bratzler shear force (WBSF) and slice shear force (SSF) tenderness measures in longissimus steaks from market dairy cows fed varying levels of zilpaterol hydrochloride (0 vs. 7.5 ppm)

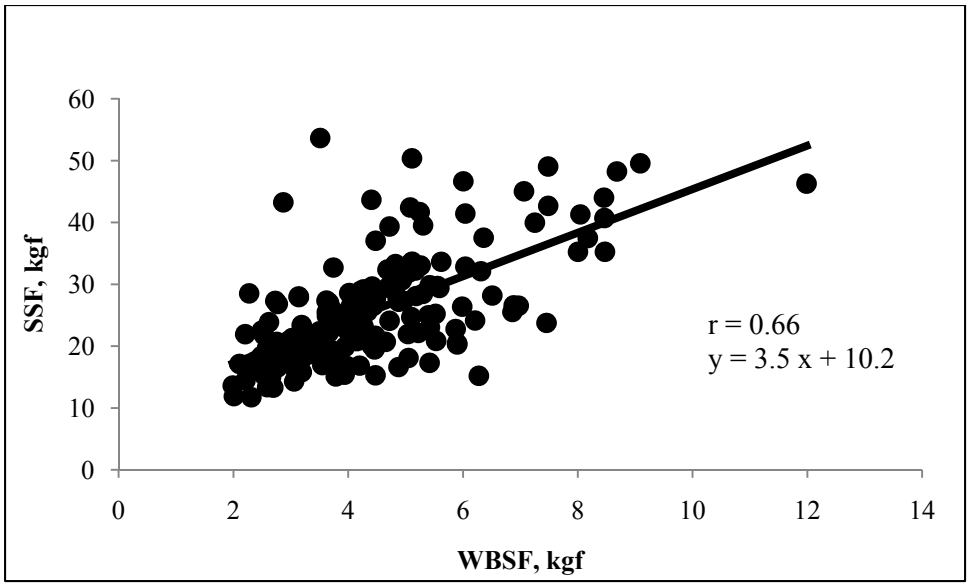

Figure 4.2. Correlation between Warner-Bratzler shear force (WBSF) and slice shear force (SSF) in longissimus steaks from market dairy cows.

Table 4.4. Long-chain fatty acid composition of subcutaneous adipose tissue from market dairy cows supplemented with zilpaterol hydrochloride (ZH)

	ZH Inclusion level, ppm			
Item, % of total fatty acids	CT	ZH	SEM	*P*-value
C10:0	0.04	0.07	0.03	0.51
C12:0	0.11	0.11	0.02	0.89
C13:0	0.06	0.00	0.04	0.37
C14:0	3.47	3.00	0.13	0.02
C14:1	1.92	1.70	0.20	0.45
C15:0	0.58	0.48	0.10	0.52
C16:0	27.36	27.12	0.39	0.67
C16:1	8.67	7.91	0.54	0.34
C17:0	0.69	0.61	0.06	0.34
C18:0	8.61	9.07	0.74	0.66
C18:1	44.49	46.18	0.75	0.12
C18:1 *trans*-9	0.24	0.21	0.05	0.61
C18:1 *trans*-10	0.61	0.37	0.12	0.19
C18:1 *trans*-11	0.95	1.12	0.11	0.28
C18:1 *cis*-9	40.53	42.59	0.66	0.04
C18:1 *cis*-11	2.15	1.89	0.15	0.24
C20:0	0.05	0.08	0.03	0.49
C21:0	0.26	0.31	0.03	0.26
C22:0	0.19	0.19	0.04	0.94
cis-9, *cis*-12	2.35	2.02	0.15	0.13
C18:3	0.28	0.28	0.02	0.96
cis-9, *trans*-11	0.60	0.53	0.05	0.29
cis-11, *trans*-13	0.04	0.04	0.00	0.48
trans-10, *cis*-12	0.02	0.01	0.00	0.29
cis-9, *cis*-11	0.14	0.13	0.01	0.95
trans-9, *trans*-11, *trans*-10, *cis*-12	0.04	0.04	0.01	0.82
C20:4	0.03	0.02	0.00	0.13
C22:5	0.02	0.01	0.00	0.43
SFA[1]	41.41	41.06	1.00	0.81
MUFA[2]	55.07	55.79	1.00	0.62
PUFA[3]	3.51	3.09	0.17	0.09

[1]SFA is the sum of the percentages of: C10:0, C12:0, C13:0, C14:0, C15:0, C16:0, C17:0, C18:0, C20:0, C21:0, C22:0

[2]MUFA is the sum of the percentages of: C14:1, C16:1, C18:1

[3]PUFA is the sum of the percentages of: C18:3, *c*-9*t*-12 conjugated linoleic acid (CLA), *c*-9*t*-11 CLA, *c*-11*t*-13 CLA, *t*-10*c*-12 CLA, *t*-9*t*-11*t*-10*c*-12 CLA, C22:4, C22:5

Chapter 5

CONCLUSIONS

Consumer acceptability is driven by the ability of the red meats industry to provide the purchaser a wholesome, quality product. Improvements in feeding strategies, like the introduction of β-AA, have given producers the ability to improve feed efficiency and growth while at the same time improving lean yields in beef animals. Research has shown that β-AA have the ability to improve yields by greatly stimulating lean tissue growth without having detrimental effects on intramuscular fat in market cows.

In this study, thirty-four market dairy cows were used to investigate the effects of preslaughter feeding with zilpaterol hydrochloride (ZH) supplementation on growth performance, carcass characteristics, composition, and tenderness. Zilpaterol hydrochloride supplementation proved not to be effective in improving feedlot performance for the market cows in this study. However, ZH greatly improved carcass yield traits without compromising carcass quality. Lean tissue yield benefited from ZH supplementation not only in increasing weight, but also by increasing percentages of cold side weight. This change in primal, subprimal, and cut yield shows that ZH has the ability to improve returns of market dairy cows through a well implemented preslaughter feeding program. As expected, supplemental feeding with β-AA caused a decrease in tenderness for the middle meats of these market dairy cows; however, there seemed to be little to no effect on the flat iron and tip center added-value cuts. To date, this was the first research of this kind investigating ZH and market dairy cows; thus, more research is needed to evaluate different feeding periods, with or without ZH, and their effects on yield and quality in market dairy cows.