EFFECT OF ZILPATEROL HYDROCHLORIDE SUPPLEMENTATION OF BEEF AND DAIRY STEERS ON THE COLOR STABILITY OF TOP SIRLOIN BUTT STEAKS

By

JENNIFER NICOLE GREEN

Bachelor of Science

Oklahoma State University

Stillwater, Oklahoma

2006

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
May, 2008

EFFECT OF ZILPATEROL HYDROCHLORIDE

SUPPLEMENTATION OF BEEF AND DAIRY

STEERS ON THE COLOR STABILITY

OF TOP SIRLOIN BUTT

STEAKS

Thesis Approved:

Dr. Deborah VanOverbeke

Thesis Adviser

Dr. Christina Dewitt

Committee member

Dr. Gretchen Hilton

Committee member

Dr. A. Gordon Emslie

Dean of the Graduate College

ACKNOWLEDGEMENTS

First and foremost, I would like to express my sincere appreciation to my major advisor, Dr. Deborah VanOverbeke for giving me the opportunity to pursue a M.S. degree from OSU. I appreciate her willingness to critique my work and assistance when I was writing my thesis. Secondly I would like to thank my other committee members Dr. Christina Dewitt and Dr. Gretchen Hilton for their expertise and guidance. I would also like to thank Dr. Brad Morgan, Dr. Stan Gilliland and Jake Nelson for always pointing me in the right direction and for their unending patience and support.

Additionally I would like to thank Kris for all of her willingness to always be of help. Also, my sincere thanks to my fellow graduate students for all their help and friendship along the way. A special thanks to the crew in FAPC for all their help on my project. To the numerous others in the animal science department (professors, lab technicians, secretaries), your assistance and support does not go unnoticed or unappreciated!

It goes without saying that I would not have been able to take on this challenge without the unconditional love and support of my family; mom, dad, Aubrie, Tanner, and grandma, without you guys I don't know what I would do! I am so very grateful for the knowledge that I have learned while attending school at OSU and for the family and friends that have touched my life!

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Increasing animal performance, improving carcass characteristics, and enhancing meat quality are main objectives of research being performed in meat animal production. Satisfying the consumer's desire for a consistent product is the goal of meat producers and retailers alike. Lately, the food industry's attention has focused on fat reduction in beef products.

Consumers are concerned about fat in meat for health reasons (Wallace et al., 1987). Because consumer demands for leaner meat have increased, more emphasis is placed on the carcass composition having less fat and more muscle (Geesink et al., 1993). Producers and packers must be responsive to consumer demands and find ways to reduce the fat content of meat (Wallace et al., 1987). In the most recent 2005 National Beef Quality Audit, Oklahoma State University meat scientist Brad Morgan commented, "We're not winning the war on fat. About 15% [beef carcasses] are too fat, but still may not be marbled well enough (NBQA, 2005)." Even though today's consumer is health conscious, they still insist on having an enjoyable eating experience. It is necessary that the beef industry take whatever measures are necessary to reduce external fat without reducing the intramuscular fat that is required for flavor and tenderness in beef cattle (Berry and Leddy, 1990).

Feed efficiency is the primary driver of profitability for meat production animals (Linn and Salfer, 2006). The rising cost of animal feed is causing the industry to look for new solutions in increasing animal performance. Providing feed to cattle is the largest expense in most commercial beef production enterprises, and any attempt at improving the efficiency of feed use will help reduce input costs (Arthur et al., 2001). Zilpaterol hydrochloride (ZH) is a growth stimulant that has been shown to improve the conversion of feed and increase body mass gain of cattle in feedlots. Zilpaterol hydrochloride is a β-agonist which acts as a chemical messenger that can be used to produce less fat and more lean to the carcass of meat animals (Hanrahan, 1987). β-agonists are also shown to improve the growth rate of cattle and improve feed efficiency.

Meat quality is an important criterion that influences the decision of a consumer to purchase beef (Sami et al., 2004). Consumers visually evaluate the appearance of meat before they make a purchase. It has been reported that color is one of the greatest factors in determining whether or not a meat cut will be purchased (Kropf, 1980), because consumers use meat color as an indicator of wholesomeness. The typical consumer purchases meat that is bright ‘cherry red’ in color. Because color of beef is critical to consumer purchasing decisions, it is important to investigate those factors that influence color stability (Hood, 1980).

The question of what happens to the overall color of meat when a β-agonist has been used to increase carcass composition has yet to be answered. The objectives of this study were to evaluate color stability of top sirloin butt steaks from cattle that have been fed a β-agonist, ZH, Zilmax®, when placed in either modified atmosphere packages or polyvinylchloride film packages.

CHAPTER II

REVIEW OF LITERATURE

β-agonists

The desire for leaner meat has increased among consumers and, therefore, the demand for a lean carcass has grown. The need for a leaner beef carcass led researchers to investigate the treatment of cattle with β-agonists to reduce the accumulation of fat on a carcass while depositing lean muscle mass in many species including lamb, swine, chicken, and beef (Allen et al., 1987; Merkel, 1988; Muir, 1988).

A β-agonist redirects already existing nutrients toward intensified protein synthesis and, as a result, there is more muscle growth and less fat deposition. This redirecting of metabolism in favor of protein synthesis has prompted the referencing of some agonists as repartitioning agents (Reeds and Mersmann, 1991). Because β-agonists repartition metabolism, they decrease fat deposition in the body and favor muscle protein accretion (Milagro et al., 2004). Successful repartitioning will improve animal efficiency because it takes more energy to produce 1 kg of fat than it takes to produce 1 kg of muscle (Van Es, 1977).

β-agonists were initially looked into because of their potentially positive effects on human health. β-agonists were originally used for treating asthmatics, obesity, and muscle atrophy. These hormones are responsible for heart rate, regulating smooth muscle contraction, blood pressure, and lipolysis (Mersmann, 1989). A β-agonist is characterized as an agonist because it activates the β-receptor on the muscle that surrounds the airways. These agonist receptors were first classified by Ahlquist in 1948 into either alpha (α) or beta (β) receptors. "Alpha receptors are responsible for gut contraction and cerebral, skin and salivary gland arterioles, and beta receptors are responsible for heart rate, contractility, bronchodilation and stimulation of lipolysis" (Mersmann, 1989).

Emery et al. stated in 1984 that stimulation of the involved β-receptors might lead to a decrease in fat and an increase in muscle. β-agonists are organic molecules that bind to receptors present on mammalian cells. Activation of the adrenergic receptor is initiated by the binding of the analogue or catecholamine to the receptor (Dawson et al., 1990). They have been shown to increase protein content and skeletal muscle mass through hypertrophy and also reduce adipose tissue (Yang and McElliott, 1989).

β-receptors have been broken down into two classifications of β-1 and β-2 receptors characterized by the differing affinity for adrenalin and nor-adrenalin (Lands et al., 1967). Also according to Lands et al. (1967), the β-1's have an affinity for two catecholamines while the β-2 has exhibited an affinity for adrenalin. A β-1 agonist contracts the muscle of the heart whereas a β-2 agonist causes smooth muscle relaxation. β-agonists activate through stimulating β-2 adrenoceptors, which predominate in the skeletal bovine muscle (Sillence et al., 1991). Research suggests that β-agonists also increase the flow of blood to skeletal muscle, and the more abundant amount of nutrients are accessible to the muscle for growth (Mersmann, 1998; Mills, 2002).

Research has shown that the use of specific β-agonists can optimize the performance of cattle without considerably comprising the meat quality (Strydom et al., 2007). When the feedlot diet was supplemented with a specific β-agonist for 30 or 50 days, the shelf life of steaks from the loin and rump was extended during a retail display study at 4℃, after having been aged for 0 or 28 days (Dikeman, 2007).

Zilpaterol Hydrochloride

Zilpaterol hydrochloride (ZH) is a growth-partitioning agent that is manufactured by Intervet under the trade name Zilmax®. It is a feed additive that enhances growth in cattle and is designed to redirect nutrients toward leaner meat production. Zilpaterol hydrochloride was approved in Mexico and South Africa more than ten years ago as a feed additive used to improve feedlot performance (Avendano-Reyes et al., 2006). In 2006, the United States approved ZH for use in cattle because documented research shows that it improves feed efficiency, increases carcass leanness, and increases the rate of weight gain (Avendano-Reyes et al., 2006). The only stipulation is that it be fed to cattle in confinement feedlots during the last 20 to 40 days on feed. The addition rate of ZH to feed is 6.8 grams/ton (7.5 ppm). Sixty to ninety milligrams of ZH should be given per head per day on a 90% dry matter basis.

Research shows that ZH improves dressing percent, growth performance, and carcass muscling in cattle (Dikeman, 2007). Recent research has confirmed that dietary supplementation of ZH also improves feedlot performance of steers when based on feed efficiency and average daily gain (Avendano-Reyes et al., 2006). This study showed that ZH improved ($P < 0.01$) the gain to feed ratio and the average daily gain (ADG) by 26 % when compared to steers who had not been fed a feed supplement (Avendano-Reyes et al., 2006).

Unlike other types of growth promotants or hormones, ZH does not have a potential negative potency. It is not like other β-agonists that have been used in research before because ZH is synthetic (Dikeman, 2007). There is no need to worry about possible toxicity effects in humans from consuming meat from animals supplemented with ZH because it is metabolized in rapid succession and quickly cleared from the tissues of cattle (Dikeman, 2007).

Zilpaterol hydrochloride has a weak affinity for particular receptors thus indicating its conventional activity as a repartitioning agent (Strydom et al., 2007). This means that when compared to other β-agonists with higher affinities to receptors, ZH should have a less obvious negative effect on meat tenderness. According to Strydom et al. (2007), ZH showed no significant effect on meat tenderness when the period of supplementation was limited to 30 d. Strydom et al. (2007) also expects that there will be no negative effect on the tenderness of the meat when supplemented with ZH.

Importance of Meat Color

In today's meat industry, meat quality depends on the acceptable color of the meat in the retail case. The typical consumer of beef purchases meat that is bright ‘cherry red’ in color. Preservation of the bright ‘cherry red’ color is necessary in order for consumers to be interested in purchasing meat. When purchasing a specific cut of meat, the only criteria consumers have to go by is the visual appearance of that meat to determine quality and wholesomeness. Thus, visual determination of meat is the best way for estimating consumer perception and their willingness to buy a piece of meat at the store. For this reason, consumers rely heavily on meat color as an indicator of freshness when making purchases (Jeremiah, 1982; Kropf, 1980).

An important aspect of the perception of beef in today’s meat industry is whether or not the product is visually appealing. This is because there are three sensory properties that consumers use to judge the quality of meat: appearance, flavor, and texture (Liu et al., 1995). Appearance is the most significant of these because it vigorously influences whether or not the consumer makes a decision to purchase the beef (Kropf, 1982; Faustman and Cassens, 1990). Appearance is used by consumers to assess the quality and wholesomeness of the meat they intend to purchase.

Consumers use discoloration in order to determine the freshness and wholesomeness of the meat they purchase (Mancini and Hunt, 2005). When making purchases, consumers will not buy meat that discolors and turns dark quickly in the retail case (Risvik, 1994). As a consequence, close to 15% of retail beef being sold has to be discounted due to discoloration, adding up to nearly one billion dollar losses yearly (Smith et al., 2000). By improving color stability of meat, less meat will be thrown away and discounted due to discoloration.

The main protein responsible for meat color is myoglobin; meat color is dependent on the chemical state and amount of myoglobin. The color of beef is due to three main states of myoglobin: deoxymyoglobin, oxymyoglobin, and metmyoglobin (Livingston and Brown, 1982). The purple color is associated with deoxymyoglobin. Oxygenation of deoxymyoglobin results in oxymoglobin (Mancini and Hunt, 2005) which is responsible for the bright ‘cherry red’ color of fresh meat. Oxymyoglobin is the most desirable meat color. After several days or hours of air exposure, oxymoglobin turns to metmyoglobin, which results in the brown pigmentation.

A main ingredient in the stability of meat color is the reduction of metmyoglobin. Metmyoglobin conversion in beef products is very important because consumers’ purchasing decisions of red meats are based on product color (Behrends et al., 2003). Oxymyoglobin reacts with oxygen to form metmyoglobin which has a brown color that consumers correspond with a loss of quality (Hood & Riordan, 1973). Consequently, every muscle has distinctive postmortem chemistry and color stability when it is exposed to atmospheric oxygen (Hood, 1980).

When determining USDA quality grades for specific beef carcasses the color of the muscle is taken into account (USDA, 1997). The USDA graders must grade the lean color in relation to the maturity of the carcass. A dark cutter grades lower because the muscle is dark in color and, therefore, unappealing to consumers. It should also be noted that animals of different age, different muscles, and different species produce varying degrees of myoglobin. The older an animal, the more myoglobin will be present in the muscle. Cattle have more myoglobin in the muscle than swine or chickens which explains why beef has a more intense red color than do pork or chicken.

Impact of Packaging on Meat Color Stability

Modern packaging techniques are expected to maintain the highest quality of meat color. The meat color stability can be extended by inhibiting or stalling the microbial growth and or limiting oxidation reactions that can cause the meat to turn from red to brown. This can be accomplished by manipulating the meat microenvironment (Hotchkiss and Galloway, 1989). The inhibitory effect of CO_2 on microbial growth has been well documented (Clark and Lentz, 1972; Huffman et al., 1975; Silliker and Wolfe, 1980; Taylor and McDougall, 1973). Modified atmosphere packaging techniques (MAP) and vacuum packaging are being used commercially in the food industry to extend the color and shelf-life of meat.

The impact of packaging on the stability of beef sold to retail stores can have its advantages and disadvantages. Some advantages of marketing frozen retail beef are lower total equipment cost, centralized retail cutting, greater marketing flexibility, and more uniform and improved sanitation (Liu et al., 1995). The rate of fading color from red to brown of beef is affected by the packaging methods, illumination level of the light bulbs, storage temperature, and muscle type (Kropf, 1982; MacDougall, 1982; Anderson and Skibsted, 1991; Lanari et al., 1989).

According to prior research, meat color has been known to be affected by packaging conditions but not storage temperature (Sorheim et al., 1996). Modified atmosphere packaging can be categorized into two groups, high oxygen MAP and low oxygen MAP (Mancini and Hunt, 2005). The type of gaseous atmosphere that surrounds the meat in the package has been shown to be one of the most important factors affecting the overall color stability during storage of meat (Mancini and Hunt, 2005). The most common gases that are used for packaging of meat are carbon dioxide, nitrogen, and oxygen (Young et al., 1999). Carbon dioxide combines with myoglobin to form carboxymyoglobin, which has been demonstrated to be more stable to oxidation than oxymyoglobin and gives an appealing bright 'cherry red' color to meat (El-Badawi et al., 1964).

Discoloration is a major deterrent to consumers when purchasing meat from a retail case (Behrends et al., 2003). In order to preserve the appearance of meat in the retail case, slowing down or preventing the formation of metmyoglobin on the surface of the meat is necessary (Gill, 1996). When packages are stored in a lighted retail display case, the surface of meat acquires more metmyoglobin than if it were stored in the dark (Lawrie, 1991; Seyfert et al., 2007).

The type of package used in displaying fresh beef products can influence the perception of the color red in meat. Research shows that meat packaged with some sort of film contact, like traditional polyvinylchloride (PVC) film packaging, was allegedly more red than the meat packaged with a headspace (Carpenter et al., 2001). Consumer preference for bright 'cherry red' beef packaged using PVC might slow down the industry's move toward MAP packaging (Carpenter et al., 2001). The inherent draw-back to MAP packaging is that rancidity can develop while the meat color maintains a desirable redness during storage (Jayasingh et al., 2002).

Impact of Feed Supplementation on Meat Color Stability

By maintaining the bright 'cherry red' color of fresh meat at the retail level there will be an increased shelf life and better probability of a sale in the original package. This has led to increasing the use of feed supplementation as a way to extend the shelf life color of meat. Recent research has proposed that dietary ingredients may have an impact on the color stability of meat. Research studies indicate that dietary vitamin E supplementation of steers causes accumulation of α-tocopherol in muscle tissue, delaying oxymyoglobin and lipid oxidation, thereby prolongs the color stability of beef (Arnold et al., 1992; Arnold et al., 1993; Chan et al., 1996; and Liu et al., 1996). Dietary delivery of α-tocopherol via supplementation seems to be the most effective means for obtaining the color-stabilizing effect (Faustman et al., 1998). By utilizing supplementation of vitamin E in diets fed to steers, we can improve the color stability of meat cuts sold commercially to consumers. By increasing levels of vitamin E fed in finishing diets there is an increase in shelf-life and color stability of cuts of meat (Arnold et al., 1992; Liu et al., 1995).

Meat Color Stability and β-agonist's

Research done on the β-agonist salbutamol used in supplementing feed to swine found the amount of redness in meat, measured by the amount of a*, was decreased (Warriss et al., 1991). Meat from calves supplemented with a β-agonist have been expected to be paler than calves receiving no supplement (Berge et al., 1993). Vestergaard et al. (1994) found that there was less redness in meat in bulls fed the β-agonist, cimaterol.

A research trial showed that ZH supplementation for 30 or 50 d significantly enhanced the shelf life of rump and loin steaks and topside mince during a retail display at 4 °C (Strydom et al., 2007). Both 30 and 50 d of ZH supplementation increased the color stability of mincemeat by 1 d and 50 d of ZH supplementation seemed to have a greater effect on the color stability of the rump by increasing it's shelf life by 1 d (Strydom et al., 2007). Given the differences in research results on the impact of β-agonist supplementation on color stability, more research should be conducted to determine the shelf-life of steaks from cattle supplemented with ZH in various packaging technologies.

CHAPTER III

EFFECT OF ZILPATEROL HYDROCHLORIDE SUPPLEMENTATION OF BEEF STEERS ON THE COLOR STABILITY OF TOP SIRLOIN BUTT STEAKS PLACED IN POLYVINYLCHLORIDE FILM OR MODIFIED ATMOSPHERE PACKAGES

ABSTRACT

Steaks from paired top sirloin butts (n = 66 pairs + 2 singles) were used to determine the effects of supplementing zilpaterol hydrochloride (ZH) to beef steers on color stability. The current study compared the effects on top sirloin butt steaks fabricated from steers supplemented for 0 d, 20 d, 30 d, or 40 d. Sixty-six pairs of top sirloin butts (n = 14 pairs + 2 singles - 0d ZH, n = 17 pairs - 20 d ZH, n = 18 pairs - 30 d ZH, and n = 17 pairs - 40 d ZH) were collected from carcasses at Tyson Fresh Meats in Amarillo, TX and sent to Oklahoma State University. One-half of the subprimals were enhanced and three 2.54 cm steaks (d 1, 3, and 5) from each enhanced subprimal were packaged under modified atmosphere packaging (80% O_2 / 20% CO_2). The other half of the subprimals were aged for a total of 21 d and then three 2.54 cm steaks (d 1, 3, and 5) were fabricated from each unenhanced subprimal and packaged under polyvinylchloride (PVC) film packaging. Packages were evaluated for color attributes and discoloration. There was no significant interaction between any of the four treatment groups (0 d, 20 d, 30 d and 40 d) supplemented with ZH and d of retail display. Beef steaks packaged with PVC from 30 d of supplementation with ZH had a tendency to produce a redder steak with higher a* values. With the exception of steaks on d 5, ZH had no significant effect on the subjective visual color and discoloration of top sirloin butt steaks packaged with PVC when

stratified by day of retail display. Modified atmosphere packaged steaks from 20 d of supplementation with ZH were redder (P < 0.05) than 30 or 40 d of supplementation, but were similar to the control steaks. Modified atmosphere packaged steaks, as expected, became progressively darker ($P < 0.05$) from d 1 to d 5 objectively, and subjectively darker ($P < 0.05$) from d 2 to d 5. In conclusion, while this study documents that slight differences do exist in color stability in each packaging environment the differences are not of a magnitude of concern. If recommending a period of supplementation, 20 to 30 d would be suggested to result in, on average, the brightest, reddest steaks possible.

INTRODUCTION

The use of pharmacologically active compounds to alter the carcass composition of animals produced for human consumption has been the result of the past twenty to thirty years of research (Hanrahan, 1987). The composition of an animal's carcass has become increasingly more important in recent years because the shift in consumer demand for leaner meat, thus making the need for leaner carcasses (Allen et al., 1987).

It has recently been shown in research that β-agonists modify carcass composition considerably (Ricks et al., 1984). β-agonists act as chemical messengers and can be used to alter metabolism putting less fat and more lean on a carcass of meat animals (Hanrahan, 1987). The effect that these compounds have on carcass composition increases the deposition of protein while reducing the accretion of fat (Hanrahan, 1987).

β-agonists have been shown to replace the traditional growth promoters of production based animals. Zilpaterol hydrochloride (ZH) is not considered a steroid. It is a growth stimulant that has been shown to improve the conversion of feed and body mass gain of cattle in feedlots. The use of β-agonists has shown to improve carcass composition of beef by producing a leaner carcass. Dikeman (2007) documented that ZH improves overall dressing percent, growth performance, and carcass muscling. Furthermore, continuing research has been done to evaluate what effect β-agonists have on other outliers of carcass merit.

While numerous studies have evaluated the impact of β-agonists on carcass quality, limited data exists on the effect of β-agonists on color stability of steaks in retail environments. Therefore, the objective of this experiment was to determine the effect of ZH supplementation on the color stability of top sirloin butt beef steaks displayed in a retail case setting.

MATERIALS AND METHODS

Meat Samples

Steers fed at Cactus Research were divided into four different treatment groups, and were either supplemented ZH for 0, 20, 30, or 40 d. All ZH was withdrawn from feed 3 d prior to harvest. After feeding, steers were harvested at Tyson Fresh Meats in Amarillo. Carcasses were chilled at 3°C until grading when USDA Select carcasses were selected for muscle color evaluation. Sixty-six pairs of top sirloin butts (n = 14 pairs + 2 singles – 0 d ZH, n = 17 pairs – 20 d ZH, n = 18 pairs - 30 d ZH, and n = 17 pairs of 40 d ZH) were individually identified and tagged prior to fabrication of the carcasses. Subprimals were vacuum packaged and transported in two groups (n = 32 + n = 34) to the Food and Agricultural Products Center (FAPC) located on the Oklahoma State University campus for further analysis.

Postmortem Handling

Upon arrival to FAPC, one top sirloin butt from each pair (n = total of 66 pairs) was assigned to be packaged under modified atmosphere packaging (MAP) and the other top sirloin butt was to be packaged under a traditional polyvinylchloride film overwrap (PVC).

The top sirloin butt assigned to be packaged under MAP was aged in the dark in the vacuum packed bag it was shipped in for 7 d at 3°C. On d 7, subprimals were opened, and the caps were removed from the top sirloin butts leaving the *gluteus medius.* The stitch pump enhancer was standardized by injecting samples with the enhancement solution. Top sirloin butts were weighed before and after to make sure the pump was accurate. Each *gluteus medius* was enhanced at 110% of the original weight with a solution containing 0.05% NatureGuard rosemary™ extract, 0.35% Brifisol 85 instant phosphate, 0.3% non-iodized salt, and a mixture of water and ice. The *gluteus medius* was then allowed to equilibrate for 10 to 15 min. Following enhancement and equilibration, three 2.54 cm-thick steaks were cut using a sanitized standard meat slicer. Individual steak weights were recorded using a top loading balance. Steaks were then placed into rigid, case-ready plastic modified atmosphere (MAP) trays with absorbent pads. Trays were flushed with 80% oxygen and 20% carbon dioxide, and heat-sealed with a barrier film (LID 1050 film, Cryovac, Sealed Air, Duncan SC) using an in-house G. Mondini modified atmosphere packaging (MAP) machine (Model CV/VG-5, G. Modini S.P.A. Cologne, Italy). Gas headspace of empty packages was verified with an analyzer (Model HS-750, MOCON Modern Controls Inc., Minneaplois, MN) within 10 min after packaging to ensure gas mixture was correct. The MAP packaged steaks were then placed in boxes in a dark room at 4°C to simulate dark storage and transport for 7 d. Steaks were then displayed in a retail-style coffin case under 24 h continuous cool-white fluorescent light (1,600 to 1,900 lux) at 2 to 4°C for 5 d. All packages were rotated daily from side-to-side and front-to-back of the retail-style coffin case to minimize any differences in light intensity or temperature due to location.

The top sirloin butt assigned to be packaged with PVC was aged in the dark for 21 d at 3°C. On d 21, subprimals were weighed to obtain the initial bagged weight of each subprimal, and the weight was recorded. The bags were opened, and the top sirloin butts were blotted to remove excess moisture and weighed again. The bags were washed and placed in the smokehouse to dry at 32°C for 3 h. After they were dried, each bag was weighed, and weights were recorded. The caps were removed from the top sirloin butts leaving the *gluteus medius.* Three 2.54 cm-thick steaks were cut using a sanitized standard meat slicer. Individual steak weights were recorded using a top loading balance. Steaks were then placed on styrofoam trays with absorbent pads and overwrapped with PVC film. Steaks were then immediately displayed in a retail-style coffin case under 24 h continuous cool-white fluorescent light (1,600 to 1,900 lux) at 2 to 4°C for 5 d. All packages were rotated daily from side-to-side and front-to-back of the retail-style coffin cases to minimize any differences in light intensity or temperature due to location.

Retail Shelf Life

Retail display steaks were evaluated using objective and subjective measurement. Visual color of steaks was subjectively evaluated according to the guidelines for meat color evaluation (AMSA, 1991). A trained panel (n = 6) evaluated color once a day for 5 d. Each trained panelist passed the Farnsworth 100 Hue Test with an error score of less than 60 and had normal color vision. Initial color was evaluated; panelists were instructed to only characterize the initial appearance of the muscle on the d 0 of each display (1 = purplish pink red or red or reddish tan; Appendix 1). Surface discoloration was not evaluated on d 0. After d 0, color was evaluated once a day at 8 am +/- 1 h. Steaks were scored based on lean color (1 = very bright red or pinkish red, 5 = moderately dark red or pinkish red, 8 = tan to brown) and percent surface discoloration (1 = None, 0%, 7 = Total, 100%; Appendix 2).

Instrumental Color

The objective evaluation of color from each steak was measured using a Hunterlab MiniScan Spectrophotometer (Model HunterLab, Reston, VA). At the beginning of each day's evaluation, the instrument was calibrated with a white calibration tile and a black calibration tile. Each steak was evaluated by obtaining the average score from three sections of each steak, avoiding any seam fat, on d 1, 3, and 5. Each average included a value for L* (lightness; 0 = black and 100 = white), a* (red to green; positive values = red, negative values = green), and b* (yellow to blue; positive values = yellow, negative values = blue).

Statistical Analysis

All results were analyzed using the mixed models procedure (PROC MIXED, SAS Institute, Cary, NC). Data were analyzed to determine the treatment effect (days supplemented with ZH) on the color stability of the steaks. The model included treatment (days supplemented with ZH), retail display day, and the treatment by day interaction as main effects. When a significant F test for one of the main effects or the interaction was observed, mean separation was performed using the least significant difference. All results were evaluated at the nominal significance level of 0.05.

RESULTS AND DISCUSSION

Least square means are provided for each of the four treatment groups. There was no significant interaction between days of supplementation and retail display day on color measured objectively. This is an agreement with research done by Avendano-Reyes et al. (2006), who said that meat color was not altered by β-agonist supplementation.

Objective values indicate that steaks became darker and redder as number of days of display increased. This agrees with the current research that documents an increase in a* values in meat color for animals supplemented with ZH (Avendano-Reyes et al., 2006). Steaks from 30 d of supplementation with ZH had a tendency to produce redder steaks with higher a* values. Overall, 30 d of ZH produced steaks with increased b* values ($P < 0.05$). There has been a trend to paler meat in research studies that used a β-2 agonist (Geesink et al., 1993; Vestergaard et al., 1994). Initial visual color values for all days that ZH was fed were between 4 and 5, which indicates that all steaks were initially moderately light cherry red to cherry red (Table 1).

Steaks, as expected, became darker from d 1 to d 5. Avendano-Reyes et al. (2006) found that the meat from all treatment groups supplemented with a β-agonist darkened with time, and the darkening effect was even more evident in the ZH group supplemented during the final 33 days of the experiment. Overall the L*, a*, and b* scores decreased from d 1 to d 5. The brightness of steaks decreased ($P < 0.05$) from d 1 to d 3, but remained unchanged from d 3 to d 5. Redness (a*) and yellowness (b*) decreased ($P < 0.05$) daily from d 1 to d 3 and d 3 to d 5 (Table 2).

Overall, the subjective color of the PVC packaged steaks became significantly ($P < 0.05$) darker from d 2 to d 5. The panelists, on average, scored the steaks with a visual color score of slightly dark red on d 2 compared to dark red or dark pinkish red on d 5 (Table 3). The borderline acceptability score to the panelist was 5.5 for scoring visual color of the steaks. This means that d 2 through 4 the color was acceptable to panelists and that d 5 the color was not visually acceptable. The trained panelists agreed that the amount of surface discoloration significantly increased (*P* < 0.05) from d 2 to d 5. Surface discoloration increases progressively during both storage and retail display of beef steaks (Jeremiah et al., 1991). Surface discoloration was scored as slight discoloration (1-19%) on d 2 compared to modest discoloration (60 to 79%) on d 5 (Table 3).

The days of supplementation with ZH had no effect on L* or a* when stratified by day of retail display. Steaks from cattle supplemented for 30 d had a significantly (*P* < 0.05) higher b* value on d 3 and d 5 when compared to 0 d and 40 d supplemented cattle (Table 4). Yellowness, b* values, usually remains unexplained in literature, but in some research studies it has an important role in beef color during the first 5 d of storage (Insausti et al., 1999). According to Jeremiah et al. (1991) b* is more important than a* in predicting meat color. It could be assumed the small changes in b* are just as important as substantial variations in L* and a* when related to the discoloration of beef and changes in percentages of pigments when determined by the reflectance spectra (Insausti et al., 1999).

With the exception of steaks on d 5, ZH had no significant effect on the visual color of beef type top sirloin butt steaks when stratified by day of retail display. According to the trained panelists on d 5 of retail display, steaks from cattle supplemented with 40 d significantly (*P* < 0.05) were between dark red/dark tannish red and a tannish red/tannish pink steak, or unacceptable color, on d 5, whereas steaks from cattle supplemented with 30 d were scored moderately dark red, or still acceptable in color. Days of supplementation with ZH had no significant difference among the discoloration scores when stratified by retail display day (Table 5).

Overall, 30 d of ZH produced significantly ($P < 0.05$) lighter steaks than the control or 20 d of supplementation. Steaks from 20 d of ZH were redder ($P < 0.05$) than 30 d or 40 d of supplementation, but were similar to the control steaks (Table 6). Zilpaterol hydrochloride had no effect on the b* values of the beef type top sirloin butt steaks packaged with MAP. On average, initial visual color panelists scored steaks from 20 d supplemented cattle as more cherry red ($P < 0.05$) than steaks from 30 d of supplementation. Days of supplementation of ZH had no effect on the overall visual color. Overall, 40 d of supplementation produced steaks with more overall surface discoloration than 30 d of supplementation. Research done in pork administered the β-agonist salbutamol documented that the amount of redness (a*) in meat was decreased (Warriss et al., 1991). Meat from calves treated with a β-agonist would have been expected to be paler than calves receiving no treatment (Berge et al., 1993). This research agrees with the findings of Vestergaard et al. (1994) in bulls fed the β-agonist, cimaterol, where there was less redness in meat.

Steaks, as expected, were progressively darker ($P < 0.05$) from d 1 to d 5 (Table 7). This agrees with another study's results where the redness of muscle color, based upon a* values, was lost during storage and display (Jeremiah et al., 1991). Overall, the L*, a*, and b* scores decreased from d 1 to d 5. Day 1 steaks were significantly ($P < 0.05$) brighter, redder, and more yellow than d 3 and d 5 steaks (Table 7). A loss of yellowness in color of samples, as defined by b* values, generally decreases with storage time (Jeremiah et al., 1991).

The panelists scored the beef type top sirloin butt steaks significantly (P < 0.05) darker from d 2 to d 5 (Table 8). The perception of muscle color was influenced by duration of storage and retail display (Jeremiah et al., 1991). The panelists also scored steaks as getting more discolored from d 2 to 3, 3 to 4, and 4 to 5. The steaks progressed from a discoloration score of 1.24 on d 2 to a score of 3.56 on d 5 (Table 8).

The days of ZH supplementation, when stratified by d of retail display, had no effect on b*. On d 1, 20 d steaks were darker (P < 0.05) than steaks from all other treatment groups. By d 3, 20 d steaks were similar in L* to the control and 40 d steaks but were still darker (P < 0.05) than 30 d steaks (Table 9). There was no supplementation effect on L* on d 5 of display. On d 1, there was no significant difference (P < 0.05) in a* values between all treatment groups. On d 3 of display, 20 d steaks were redder (P < 0.05) than 30 and 40 d steaks. By day 5, 20 d steaks had similar a* values to the control and 30 d steaks but were still more red (P < 0.05) than 40 d steaks (Table 9).

Zilpaterol hydrochloride produced no significant difference among the visual color scores for beef type top sirloin butt steaks displayed under modified atmosphere packaging (MAP). According to the trained panelists, on d 2 of the retail display, 40 d of supplementation significantly (P < 0.05) produced a steak with slight discoloration whereas the other steaks had no discoloration. On d 3, 40 d of supplementation also significantly (P < 0.05) produced a steak with more discoloration than the other steaks. On average, the trained panelists scored the steaks from cattle supplemented for 40 d with a small (20 to 30%) amount of discoloration, whereas the other steaks only had slight discoloration (1 to 19%). There was no significant effect of days of supplementation of ZH on the discoloration of the steaks on d 4 and 5 of retail display (Table 10).

CONCLUSION

While this study documents that slight differences do exist in color stability in each packaging environment, traditional PVC and MAP, the differences are not of a magnitude of concern. If recommending a period of supplementation of zilpaterol hydrochloride, 20 to 30 d would be suggested to result in, on average, the brightest, reddest steaks possible. It would also be more economically beneficial to the feedlot to supplement the steers' diet for 20 or 30 d vs. 40 d. Further research should be conducted to further investigate the differences between 20 and 30 d of supplementation and the impact on color.

Table 1. Effects of Zilpaterol Hydrochloride on retail display characteristics of beef type top sirloin butt steaks displayed under polyvinylchloride film packaging.

	Zilpaterol Hydrochloride (day of supplementation)					
Item	0	20	30	40	Pr > F	SEM
L*	40.30	41.22	42.18	41.16	0.35	0.75
a*	17.00	17.56	18.31	17.05	0.07	0.38
b*	16.64[b]	17.44[b]	18.40[a]	17.09[b]	< 0.01	0.32
Initial Visual Color[1]	4.85	4.68	4.31	4.72	0.22	0.19
Visual Color[2]	5.03	4.72	4.35	5.11	0.10	0.23
Surface Discoloration[3]	2.46	2.34	2.02	2.50	0.36	0.21

[1] Initial Color based on these numbers: 1= Purplish pink or red or reddish tan of vacuum packages, 2 = Bleached, pale red, 3 = Slightly cherry red, 4 = Moderately light cherry red, 5 = Cherry red, 6 = Slightly dark red, 7 = Moderately dark red, 8 = Dark red, 9 = Very dark red

[2] Visual Color (d 2,3,4,5) based on these numbers: 1 = Very bright red or pinkish red, 2 = Bright red or pinkish red, 3 = Dull red or pinkish red, 4 = Slightly dark red, 5 = Moderately dark red or pinkish red 5.5 = Borderline acceptability to panelist 6 = Dark red or dark reddish tan or dark pinkish red or dark pinkish tan, 7 = Tannish red or tannish pink, 8 = Tan to brown

[3] Surface Discoloration based on these numbers: 1 = None (0%) 2 = Slight (1 to 19%) 3 = Small (20 to 39%) 4 = Modest (40 to 59%) 5 = Moderate (60 to 79%) 6 = Extensive (80 to 99%) 7 = Total (100%)

[a,b] Least Squares Means, in a row, lacking a common superscript letter, differ (*P* < 0.05).

Table 2. Effects of day on retail display characteristics of beef type top sirloin butt steaks displayed under polyvinylchloride film packaging.

	Day of Display				
Item	1	3	5	Pr > F	SEM
L*	43.07[a]	40.15[b]	40.42[b]	< 0.001	0.40
a*	24.76[a]	16.44[b]	11.25[c]	< 0.001	0.28
b*	20.44[a]	16.86[b]	14.89[c]	< 0.001	0.20

[a,b,c] Least Squares Means, in a row, lacking a common superscript letter, differ (*P* < 0.05).

Table 3. Effects of day on the overall color and surface discoloration of beef type top sirloin butt steaks under polyvinylchloride film packaging.

	Day of Display					
Item	2	3	4	5	Pr > F	SEM
Visual Color[1]	4.16[c]	4.26[c]	4.85[b]	5.93[a]	< 0.001	0.13
Surface Discoloration[2]	2.02[b]	1.05[c]	1.91[b]	4.33[a]	< 0.001	0.14

[1] Visual Color based on these numbers: 1 = Very bright red or pinkish red, 2 = Bright red or pinkish red, 3 = Dull red or pinkish red, 4 = Slightly dark red, 5 = Moderately dark red or pinkish red 5.5 = Borderline acceptability to panelist 6 = Dark red or dark reddish tan or dark pinkish red or dark pinkish tan, 7 = Tannish red or tannish pink, 8 = Tan to brown

[2] Surface Discoloration based on these numbers: 1 = None (0%), 2 = Slight (1 to 19%), 3 = Small (20 to 39%), 4 = Modest (40 to 59%), 5 = Moderate (60 to 79%), 6 = Extensive (80 to 99%), 7 = Total (100%)

[a,b,c] Least Squares Means, in a row, lacking a common superscript letter, differ ($P < 0.05$)

Table 4. Display characteristics of beef type top sirloin butt steaks displayed under polyvinylchloride film packaging from cattle supplemented with Zilpaterol Hydrochloride and stratified by day of retail display.

		Zilpaterol Hydrochloride (day of supplementation)					
Item	Day	0	20	30	40	Pr > F	SEM
L*	1	42.23	42.85	43.76	43.45	0.46	0.75
L*	3	39.08	40.68	40.88	39.97	0.46	0.89
L*	5	39.60	40.68	41.90	40.04	0.18	0.81
a*	1	24.61	24.79	25.08	24.56	0.83	0.46
a*	3	15.79	16.54	17.40	15.79	0.21	0.60
a*	5	10.61	11.36	12.45	10.58	0.15	0.68
b*	1	19.64	20.35	21.34	20.10	0.07	0.42
b*	3	16.22[b]	16.74[b]	17.99[a]	16.47[b]	0.02	0.42
b*	5	13.74[c]	15.24[ab]	15.86[a]	14.71[bc]	0.001	0.37

[a,b,c] Least Squares Means, within a row, lacking a common superscript letter, differ ($P < 0.05$)

Table 5. Visual color and discoloration display characteristics of beef type top sirloin butt steaks displayed under polyvinylchloride film packaging from cattle supplemented with Zilpaterol Hydrochloride and stratified by day of retail display.

		Zilpaterol Hydrochloride (day of supplementation)					
Item	Day	0	20	30	40	Pr > F	SEM
Visual Color[1]	2	4.32	4.25	3.71	4.37	0.27	0.28
Visual Color	3	4.57	4.06	3.97	4.46	0.15	0.23
Visual Color	4	5.05	4.75	4.42	5.15	0.20	0.27
Visual Color	5	6.17[a]	5.80[ab]	5.30[b]	6.46[a]	0.04	0.31
Discoloration[2]	2	1.95	2.23	1.70	2.22	0.59	0.32
Discoloration	3	1.12	1.00	1.04	1.04	0.16	0.04
Discoloration	4	2.10	2.15	1.57	1.83	0.38	0.27
Discoloration	5	4.68	3.98	3.73	4.93	0.11	0.40

[1] Visual Color scale: 1 = Very bright red or pinkish red, 2 = Bright red or pinkish red, 3 = Dull red or pinkish red, 4 = Slightly dark red, 5 = Moderately dark red or pinkish red 5.5 = Borderline acceptability to panelist 6 = Dark red or dark reddish tan or dark pinkish red or dark pinkish tan, 7 = Tannish red or tannish pink, 8 = Tan to brown

[2] Surface Discoloration scale: 1 = None (0%) 2 = Slight (1 to 19%) 3 = Small (20 to 39%) 4 = Modest (40 to 59%) 5 = Moderate (60 to 79%) 6 = Extensive (80 to 99%) 7 = Total (100%)

[a,b] Least Squares Means, within a row, lacking a common superscript letter, differ ($P < 0.05$)

Table 6. Effects of Zilpaterol Hydrochloride on retail display characteristics of beef type top sirloin butt steaks displayed under modified atmosphere packaging.

	Zilpaterol Hydrochloride (day of supplementation)					
Item	0	20	30	40	Pr > F	SEM
L*	45.72[bc]	45.18[c]	47.54[a]	46.98[ab]	0.03	0.60
a*	18.68[ab]	19.50[a]	18.07[b]	17.57[b]	0.02	0.43
b*	18.39	18.41	18.61	18.24	0.48	0.17
Initial Visual Color[1]	4.48[ab]	4.77[a]	3.86[b]	4.21[ab]	0.04	0.23
Visual Color[2]	3.54	3.57	3.61	3.71	0.84	0.14
S. Discoloration[3]	2.18[ab]	2.44[ab]	2.18[b]	2.84[a]	0.04	0.18

[1] Initial Color based on these numbers: 1= Purplish pink or red or reddish tan of vacuum packages, 2 = Bleached, pale red, 3 = Slightly cherry red, 4 = Moderately light cherry red, 5 = Cherry red, 6 = Slightly dark red, 7 = Moderately dark red, 8 = Dark red, 9 = Very dark red

[2] Visual Color based on these numbers: 1 = Very bright red or pinkish red, 2 = Bright red or pinkish red, 3 = Dull red or pinkish red, 4 = Slightly dark red, 5 = Moderately dark red or pinkish red 5.5 = Borderline acceptability to panelist 6 = Dark red or dark reddish tan or dark pinkish red or dark pinkish tan, 7 = Tannish red or tannish pink, 8 = Tan to brown

[3] Surface Discoloration based on these numbers: 1 = None (0%) 2 = Slight (1 to 19%) 3 = Small (20 to 39%) 4 = Modest (40 to 59%) 5 = Moderate (60 to 79%) 6 = Extensive (80 to 99%) 7 = Total (100%)

[a,b,c] Least Squares Means, in a row, lacking a common superscript letter, differ ($P < 0.05$).

Table 7. Effects of day on retail display characteristics of beef type top sirloin butt steaks displayed under modified atmosphere packaging.

	Day of Display				
Item	1	3	5	Pr > F	SEM
L*	47.57[a]	45.35[b]	45.06[b]	< 0.001	0.39
a*	19.43[a]	17.66[b]	14.42[c]	< 0.001	0.30
b*	19.11[a]	17.86[b]	16.43[c]	< 0.001	0.13

[a,b,c] Least Squares Means, in a row, lacking a common superscript letter, differ ($P < 0.05$).

Table 8. Effects of day on the overall color and surface discoloration of beef type top sirloin butt steaks under modified atmosphere packaging.

	Day of Display					
Item	2	3	4	5	Pr > F	SEM
Visual Color[1]	2.7[a]	3.44[b]	3.93[c]	4.36[d]	< 0.001	0.10
Surface Discoloration[2]	1.24[a]	2.03[b]	2.81[c]	3.56[d]	< 0.001	0.12

[1] Visual Color based on these numbers: 1 = Very bright red or pinkish red, 2 = Bright red or pinkish red, 3 = Dull red or pinkish red, 4 = Slightly dark red, 5 = Moderately dark red or pinkish red 5.5 = Borderline acceptability to panelist 6 = Dark red or dark reddish tan or dark pinkish red or dark pinkish tan, 7 = Tannish red or tannish pink, 8 = Tan to brown

[2] Surface Discoloration based on these numbers: 1 = None (0%), 2 = Slight (1 to 19%), 3 = Small (20 to 39%), 4 = Modest (40 to 59%), 5 = Moderate (60 to 79%), 6 = Extensive (80 to 99%), 7 = Total (100%)

[a,b,c,d] Least Squares Means, in a row, lacking a common superscript letter, differ ($P < 0.05$)

Table 9. Effect of Zilpaterol Hydrochloride within day on retail display characteristics of beef type top sirloin butt steaks displayed under modified atmosphere packaging.

		Zilpaterol Hydrochloride (day of supplementation)					
Item	Day	0	20	30	40	Pr > F	SEM
L*	1	48.16[a]	45.63[b]	48.72[a]	47.79[a]	0.02	0.76
L*	3	44.59[b]	44.45[b]	47.04[a]	45.33[ab]	0.05	0.75
L*	5	43.59	44.43	46.31	45.90	0.13	0.94
a*	1	19.16	20.05	19.12	19.38	0.41	0.45
a*	3	18.21[ab]	19.01[a]	16.61[b]	16.78[b]	0.02	0.65
a*	5	14.58[a]	16.52[a]	14.63[a]	11.97[b]	< 0.01	0.89
b*	1	18.99	19.24	19.25	19.97	0.36	0.15
b*	3	17.92	18.06	17.99	17.50	0.36	0.25
b*	5	16.36	16.57	16.80	15.99	0.26	0.31

[a,b] Least Squares Means, within a row, lacking a common superscript letter, differ ($P < 0.05$)

Table 10. Effect of Zilpaterol Hydrochloride within day on visual color and discoloration characteristics of beef type top sirloin butt steaks displayed under modified atmosphere packaging.

		Zilpaterol Hydrochloride (day of supplementation)					
Item	Day	0	20	30	40	Pr > F	SEM
Visual Color[1]	2	2.72	2.50	2.70	2.89	0.57	0.20
Visual Color	3	3.43	3.40	3.41	3.53	0.92	0.15
Visual Color	4	3.78	3.91	3.97	4.06	0.70	0.17
Visual Color	5	4.23	4.45	4.38	4.38	0.95	0.28
Discoloration[2]	2	1.11[a]	1.14[a]	1.15[a]	1.57[b]	< 0.01	0.10
Discoloration	3	1.70[a]	1.86[a]	1.94[a]	2.62[b]	0.02	0.22
Discoloration	4	2.65	2.80	2.48	3.31	0.11	0.26
Discoloration	5	3.24	3.98	3.17	3.85	0.21	0.34

[1] Visual Color scale: 1 = Very bright red or pinkish red, 2 = Bright red or pinkish red, 3 = Dull Red or pinkish red, 4 = Slightly dark red, 5 = Moderately dark red or pinkish red 5.5 = Borderline acceptability to panelist 6 = Dark red or dark reddish tan or dark pinkish red or dark pinkish tan, 7 = Tannish red or tannish pink, 8 = Tan to brown

[2] Surface Discoloration scale: 1 = None (0%) 2 = Slight (1 to 19%) 3 = Small (20 to 39%) 4 = Modest (40 to 59%) 5 = Moderate (60 to 79%) 6 = Extensive (80 to 99%) 7 = Total (100%)

[a,b,c] Least Squares Means, within a row, lacking a common superscript letter, differ (*P* < 0.05)

CHAPTER IV

EFFECT OF ZILPATEROL HYDROCHLORIDE SUPPLEMENTATION OF DAIRY STEERS ON THE COLOR STABILITY OF TOP SIRLOIN BUTT STEAKS PLACED IN POLYVINYLCHLORIDE FILM PACKAGES AND MODIFIED ATMOSPHERE PACKAGES

ABSTRACT

Steaks from paired top sirloin butts (n = 60 pairs) were used to determine the effects of supplementation of zilpaterol hydrochloride (ZH) on the color stability of dairy steers. This study compared the effects on top sirloin butt steaks fabricated from dairy steers supplemented for 0 d, 20 d, 30 d, or 40 d with ZH. Sixty pairs of top butts (n = 15 pairs – 0 d ZH, n = 15 pairs – 20 d ZH, n = 15 pairs – 30 d ZH, and n = 15 pairs – 40 d ZH) were collected from carcasses in Brawley Beef (Brawley, CA) and sent to Oklahoma State University. One-half of the subprimals were enhanced at 110% of their original weight; three 2.54 cm thick steaks (d 1, 3, and 5) were fabricated from each enhanced subprimal and packaged under modified atmosphere packaging (MAP) (80% O_2 / 20% CO_2). The other half of the subprimals were aged for 21 d; after aging, three 2.54 cm thick steaks (d 1, 3, and 5) were fabricated from each unenhanced subprimal, and packaged under polyvinylchloride film packaging. Overall retail display days and days of supplementation did not effect ($P > 0.05$) objective or subjective color stability of dairy type top sirloin butt steaks packaged under polyvinylchloride film. Zilpaterol hydrochloride had no effect on the L*, a*, or b* scores of the dairy top butt steaks packaged with MAP. The amount of days ZH was supplemented in the diet had no effect on the L* or a* of MAP packaged dairy steaks. Supplementation for 20 d significantly ($P < 0.05$) produced a higher

b* value on d 1 of display in MAP packaged dairy steaks. While this study documents that slight differences do exist in color stability in each packaging environment the differences are not of a magnitude of concern. Further research could be conducted to further investigate the differences between 20 and 30 d of supplementation of ZH and the impact on color.

INTRODUCTION

Consumers rely on color to measure quality and freshness of meat (Strydom et al., 2007). It has been reported that color is the single greatest appearance factor when consumers determine whether or not they will purchase a meat cut (Kropf, 1980). The meat industry has increasingly focused on modified atmosphere packaging (MAP) for fresh, case ready meats (Seyfert et al., 2007). Although MAP packaging does improve shelf life, there is muscle-to-muscle variation in the color characteristics that occur in high oxygen atmospheres (Behrends et al., 2003). Color stability is mainly a function of a muscle's metmyoglobin-reducing activity and overall oxygen consumption rate (Hood, 1980).

β-agonists are one of the most recent approaches to faster growth production in farm animals (Strydom et al., 2007). β-agonists have been shown to replace the traditional growth promoters of production based commercial animals. Zilpaterol hydrochloride (ZH) is a β-2-agonist which is particularly useful at the level of muscle metabolism (Strydom et al., 2007).

While numerous studies have evaluated the impact of β-agonists on carcass quality, limited data exists on the effect of β-agonists on color stability of steaks from dairy steers in retail environments. Therefore, the objective of this experiment was to determine the effect of ZH supplementation on the color stability of dairy type top sirloin butt steaks in a retail case setting.

MATERIALS AND METHODS

Meat Samples

Dairy steers were divided into four different treatment groups, and were fed zilpaterol hydrochloride (ZH) for 0, 20, 30, or 40 d. All ZH was withdrawn from feed 3 d prior to harvest. After feeding, they were harvested at Brawley Beef, Brawley, CA. Carcasses were chilled at 3°C until grading when carcasses were selected for muscle color evaluation. Sixty pairs of top sirloin butts (n = 15 pairs – 0 d ZH, n = 15 pairs – 20 d ZH, n = 15 pairs - 30 d ZH, and n = 15 pairs of 40 d ZH) were collected. Paired top sirloin butts (IMPS #184) were individually identified and tagged prior to fabrication of the carcasses. Subprimals were collected, vacuum packaged, and transported in two groups (n = 30 + n = 30) and shipped to the Food and Agricultural Products Center (FAPC).

Postmortem Handling, Retail Shelf Life, and Instrumental Color

Methods for postmortem handling, retail shelf life, and instrumental color were the same as described in the previous chapters for beef type steaks.

Statistical Analysis

All results were analyzed using the mixed models procedure (PROC MIXED, SAS Institute, Cary, NC). Data were analyzed to determine the treatment effect (days supplemented with ZH) on the color stability of the steaks. The model included treatment (days supplemented with ZH), retail display day, and the treatment by day interaction as main effects. When a significant F test for one of the main effects or the interaction was observed, mean separation was performed using the Least Significant Difference. All results were evaluated at the nominal significance level of 0.05.

RESULTS AND DISCUSSION

Over all retail display days, days of supplementation did not affect ($P >$ 0.05) objective or subjective color stability of dairy type top sirloin butt steaks packaged under polyvinylchloride (PVC) film (Table 11). The dairy type steaks packaged in PVC became darker, less red, and less yellow when comparing d 1 to d 3 of retail display (Table 12). This reduction in redness in muscle from β-agonist treated animals reflects a decrease in heme-pigment concentration (Moloney et al., 1994).

Across all treatment groups, visual subjective color became unacceptable ($P < 0.05$), turning from slightly dark red on d 2 to nearly tan or brown on d 5 of retail display (Table 13). Panelists also scored steaks as being more discolored ($P < 0.05$) on d 5 (80-99 %) as compared to each of the previous days of display (Table 13).

When stratified by retail display day, the days of ZH supplementation had no significant effect on L* or a*. However, there was a treatment effect on b* values on the first day of retail display. Supplementation for 20 d produced steaks with a higher b* value ($P < 0.05$) on d 1 only (Table 14). Supplementation with ZH had no effect on the subjective color score or discoloration score on any of the dairy type top sirloin butt steaks packaged with PVC (Table 15). Although not significant, supplementation with 40 d of ZH produced a steak with less discoloration on d 3, 4, and 5 than the control steaks from dairy steers which had not been supplemented with ZH (Table 15). According to Strydom et al. (2007), the *gluteus medius* steak that had been supplemented with ZH for 50 d tended to discolor less than the control steak which had not been supplemented with ZH.

Across all retail display days, ZH had no effect ($P < 0.05$) on the L*, a*, or b* scores of the dairy type top sirloin butt steaks packaged under MAP. There was also no overall effect on the initial visual color or the surface discoloration score. However, ZH supplementation did have an effect on subjective color across d 1 through 5 of retail display. On average, 20 d of ZH significantly ($P < 0.05$) produced steaks with the highest visual color score when compared to the control and 30 d of supplementation groups (Table 16).

Across all treatment groups, brightness, redness, and yellowness decreased ($P < 0.05$) from d 1 to d 3 of retail display. Redness (a*) and yellowness (b*) continued to decrease ($P < 0.05$) from d 3 to d 5 of display (Table 17). Moloney et al. (1994) indicated a decrease in the redness of meat that was treated with the β-agonist, L-644-969.

The panelists scored steaks as darker or more unacceptable (*P* < 0.05) and with more discoloration (*P* < 0.05) as retail display progressed from d 2 to d 4 to d 5 (Table 18). Steaks were scored as nearly reaching the “unacceptable” level at d 4 of display. The top sirloin butt steaks from cattle supplemented for 30 d and 0 d of ZH had an acceptability shelf life of 3 d (Strydom et al., 2007).

Stratified by day of retail display, ZH had no significant effect within day on the L*, a*, or b* scores of the dairy type top sirloin butt steaks packaged with MAP (Table 19). The effects on color were small and commercially unimportant (Moloney et al., 1994). In addition, days of supplementation with ZH did not significantly affect the amount of discoloration, as scored by panelists. However, on d 4 of retail display of the dairy type top sirloin butts packaged with MAP, steaks from steers supplemented for 20 d were darker or more unacceptable in color, as compared to control steaks and steaks from steers supplemented for 30 d (Table 20). Steaks from the 20 d supplementation group were similar in color on d 4 to those from steers supplemented for 40 d.

CONCLUSION

While this study documents that slight differences do exist in color stability in each packaging environment, PVC and MAP, the differences are not of a magnitude of concern. Zilpaterol hydrochloride had no significant effect within day or when stratified by day of retail display on the L*, a*, or b* scores of the dairy type top sirloin butt steaks packaged with MAP packaging. Over all retail display days, days of supplementation did not effect (*P* > 0.05) objective or subjective color stability of dairy type top sirloin butt steaks packaged under PVC film. There were no significant differences in the L*, a*, or b* and no differences in visual color on d 2, 3, or 5 of retail display. Further research should be conducted to further investigate the differences between 20 and 30 d of supplementation and the impact on color.

Table 11. Effects of Zilpaterol Hydrochloride on retail display characteristics of dairy type top sirloin butt steaks displayed under polyvinylchloride film packaging.

	Zilpaterol Hydrochloride (day of supplementation)					
Item	0	20	30	40	Pr > F	SEM
L*	38.58	38.45	38.30	38.58	0.98	0.52
a*	12.48	12.99	12.44	12.63	0.64	0.34
b*	13.48	14.63	13.78	13.93	0.19	0.38
Initial Visual Color[1]	4.94	4.68	4.62	4.73	0.44	0.14
Visual Color[2]	6.15	5.90	6.02	5.96	0.87	0.21
Surface Discoloration[3]	4.23	4.09	4.15	4.17	0.94	0.16

[1] Initial Color based on these numbers: 1= Purplish pink or red or reddish tan of vacuum packages, 2 = Bleached, pale red, 3 = Slightly cherry red, 4 = Moderately light cherry red, 5 = Cherry red, 6 = Slightly dark red, 7 = Moderately dark red, 8 = Dark red, 9 = Very dark red

[2] Visual Color based on these numbers: 1 = Very bright red or pinkish red, 2 = Bright red or pinkish red, 3 = Dull red or pinkish red, 4 = Slightly dark red, 5 = Moderately dark red or pinkish red 5.5 = Borderline acceptability to panelist 6 = Dark red or dark reddish tan or dark pinkish red or dark pinkish tan, 7 = Tannish red or tannish pink, 8 = Tan to brown

[3] Surface Discoloration based on these numbers: 1 = None (0%) 2 = Slight (1 to 19%) 3 = Small (20 to 39%) 4 = Modest (40 to 59%) 5 = Moderate (60 to 79%) 6 = Extensive (80 to 99%) 7 = Total (100%)

Table 12. Effects of day on retail display characteristics of dairy type top sirloin butt steaks displayed under polyvinylchloride film packaging.

	Day of Display				
Item	1	3	5	Pr > F	SEM
L*	39.97[a]	37.78[b]	37.78[b]	< 0.001	0.31
a*	20.76[a]	14.88[b]	9.26[c]	< 0.001	0.51
b*	18.56[a]	16.05[b]	15.22[c]	< 0.001	0.23

[a,b,c] Least Squares Means in a row lacking a common superscript letter differ ($P < 0.05$).

Table 13. Effects of day on the overall color and surface discoloration of dairy type top sirloin butt steaks under polyvinylchloride film packaging.

Item	Day of Display 2	3	4	5	Pr > F	SEM
Visual Color[1]	4.02[a]	5.34[b]	6.93[c]	7.76[d]	< 0.001	0.14
Surface Discoloration[2]	1.11[a]	2.88[b]	5.85[c]	6.80[d]	< 0.001	0.12

[1] Visual Color based on these numbers: 1 = Very bright red or pinkish red, 2 = Bright red or pinkish red, 3 = Dull red or pinkish red, 4 = Slightly dark red, 5 = Moderately dark red or pinkish red 5.5 = Borderline acceptability to panelist 6 = Dark red or dark reddish tan or dark pinkish red or dark pinkish tan, 7 = Tannish red or tannish pink, 8 = Tan to brown

[2] Surface Discoloration based on these numbers: 1 = None (0%), 2 = Slight (1 to 19%), 3 = Small (20 to 39%), 4 = Modest (40 to 59%), 5 = Moderate (60 to 79%), 6 = Extensive (80 to 99%), 7 = Total (100%)

[a,b,c,d] Least Squares Means, in a row, lacking a common superscript letter, differ ($P < 0.05$)

Table 14. Display characteristics of top sirloin butt steaks displayed under polyvinylchloride film packaging from dairy cattle supplemented with Zilpaterol Hydrochloride, and stratified by day of retail display.

		Zilpaterol Hydrochloride (day of supplementation)					
Item	Day	0	20	30	40	Pr > F	SEM
L*	1	39.59	39.54	40.32	40.41	0.59	0.60
L*	3	38.64	37.94	36.64	37.90	0.27	0.73
L*	5	37.52	37.87	37.95	37.41	0.90	0.60
a*	1	22.64	23.82	22.93	22.78	0.17	0.42
a*	3	9.34	9.89	9.20	9.52	0.94	0.83
a*	5	5.45	5.27	5.21	5.58	0.29	0.16
b*	1	17.08[b]	19.10[a]	17.37[b]	17.10[b]	< 0.01	0.44
b*	3	11.93	13.16	12.59	12.84	0.46	0.59
b*	5	11.44	11.64	11.38	11.86	0.84	0.42

[a,b] Least Squares Means within a row lacking a common superscript letter differ ($P < 0.05$)

Table 15. Visual color and discoloration display characteristics of dairy type top sirloin butt steaks displayed under polyvinylchloride film packaging from cattle supplemented with Zilpaterol Hydrochloride, and stratified by day of retail display.

		Zilpaterol Hydrochloride (day of supplementation)					
Item	Day	0	20	30	40	Pr > F	SEM
Visual Color[1]	2	4.02	4.01	4.07	3.96	0.99	0.21
Visual Color	3	5.74	5.13	5.13	5.36	0.76	0.46
Visual Color	4	7.03	6.75	7.08	6.84	0.75	0.25
Visual Color	5	7.80	7.76	7.81	7.68	0.70	0.08
Discoloration[2]	2	1.09	1.07	1.19	1.13	0.42	0.06
Discoloration	3	3.07	2.77	2.62	3.03	0.82	0.39
Discoloration	4	5.87	5.81	5.94	5.77	0.97	0.26
Discoloration	5	6.89	6.71	6.83	6.77	0.20	0.06

[1] Visual Color scale: 1 = Very bright red or pinkish red, 2 = Bright red or pinkish red, 3 = Dull red or pinkish red, 4 = Slightly dark red, 5 = Moderately dark red or pinkish red 5.5 = Borderline acceptability to panelist 6 = Dark red or dark reddish tan or dark pinkish red or dark pinkish tan, 7 = Tannish red or tannish pink, 8 = Tan to brown

[2] Surface Discoloration scale: 1 = None (0%) 2 = Slight (1 to 19%) 3 = Small (20 to 39%) 4 = Modest (40 to 59%) 5 = Moderate (60 to 79%) 6 = Extensive (80 to 99%) 7 = Total (100%)

Table 16. Effects of Zilpaterol Hydrochloride on retail display characteristics of dairy type top sirloin butt steaks displayed under modified atmosphere packaging.

	Zilpaterol Hydrochloride (day of supplementation)					
Item	0	20	30	40	Pr > F	SEM
L*	41.77	42.08	42.40	41.85	0.66	0.42
a*	15.99	15.75	16.38	15.94	0.87	0.58
b*	16.35	16.67	16.99	16.54	0.29	0.25
Initial Visual Color[1]	4.61	4.87	4.54	4.79	0.67	0.21
Visual Color[2]	4.54[b]	5.32[a]	4.58[b]	5.23[ab]	0.05	0.15
Surface Discoloration[3]	3.37	4.38	3.54	4.15	0.97	0.32

[1] Initial Color based on these numbers: 1= Purplish pink or red or reddish tan of vacuum packages, 2 = Bleached, pale red, 3 = Slightly cherry red, 4 = Moderately light cherry red, 5 = Cherry red, 6 = Slightly dark red, 7 = Moderately dark red, 8 = Dark red, 9 = Very dark red

[2] Visual Color based on these numbers: 1 = Very bright red or pinkish red, 2 = Bright red or pinkish red, 3 = Dull red or pinkish red, 4 = Slightly dark red, 5 = Moderately dark red or pinkish red 5.5 = Borderline acceptability to panelist 6 = Dark red or dark reddish tan or dark pinkish red or dark pinkish tan, 7 = Tannish red or tannish pink, 8 = Tan to brown

[3] Surface Discoloration based on these numbers: 1 = None (0%) 2 = Slight (1 to 19%) 3 = Small (20 to 39%) 4 = Modest (40 to 59%) 5 = Moderate (60 to 79%) 6 = Extensive (80 to 99%) 7 = Total (100%)

[a,b] Least Squares Means in a row lacking a common superscript letter differ ($P < 0.05$)

Table 17. Effects of day on retail display characteristics of dairy type top sirloin butt steaks displayed under modified atmosphere packaging.

	Day of Display				
Item	1	3	5	Pr > F	SEM
L*	42.67[a]	41.91[b]	43.02[a]	< 0.001	0.35
a*	20.76[a]	14.88[b]	9.26[c]	< 0.001	0.50
b*	18.56[a]	16.05[b]	15.22[c]	< 0.001	0.22

[a,b,c] Least Squares Means in a row lacking a common superscript letter differ ($P < 0.05$)

Table 18. Effects of day on the overall color and surface discoloration of dairy type top sirloin butt steaks under modified atmosphere packaging.

	Day of Supplementation					
Item	2	3	4	5	Pr > F	SEM
Visual Color[1]	3.62[a]	4.08[b]	5.40[c]	6.57[d]	< 0.001	0.15
Surface Discoloration[2]	1.90[d]	2.90[c]	4.77[b]	5.86[a]	< 0.001	0.20

[1] Visual Color based on these numbers: 1 = Very bright red or pinkish red, 2 = Bright red or pinkish red, 3 = Dull red or pinkish red, 4 = Slightly dark red, 5 = Moderately dark red or pinkish red 5.5 = Borderline acceptability to panelist 6 = Dark red or dark reddish tan or dark pinkish red or dark pinkish tan, 7 = Tannish red or tannish pink, 8 = Tan to brown

[2] Surface Discoloration based on these numbers: 1 = None (0%), 2 = Slight (1 to 19%), 3 = Small (20 to 39%), 4 = Modest (40 to 59%), 5 = Moderate (60 to 79%), 6 = Extensive (80 to 99%), 7 = Total (100%)

[a,b,c,d] Least Squares Means in a row lacking a common superscript letter differ ($P < 0.05$)

Table 19. Display characteristics of top sirloin butt steaks displayed under modified atmosphere packaging from dairy cattle supplemented with Zilpaterol Hydrochloride, and stratified by day of retail display.

		Zilpaterol Hydrochloride (day of supplementation)					
Item	Day	0	20	30	40	Pr > F	SEM
L*	1	42.18	43.10	42.53	42.57	0.81	0.70
L*	3	40.83	42.67	42.00	42.13	0.22	0.66
L*	5	42.57	43.61	43.47	42.57	0.58	0.80
a*	1	21.07	20.50	20.70	20.71	0.88	0.54
a*	3	14.92	13.93	15.36	15.34	0.83	1.27
a*	5	9.40	9.74	9.24	8.89	0.95	1.13
b*	1	18.25	18.67	18.70	18.57	0.61	0.27
b*	3	15.66	16.05	16.31	16.19	0.70	0.43
b*	5	15.14	15.45	15.30	15.04	0.81	0.35

Table 20. Visual color and discoloration display characteristics of dairy type top sirloin butt steaks displayed under modified atmosphere packaging from cattle supplemented with Zilpaterol Hydrochloride, and stratified by day of retail display.

		Zilpaterol Hydrochloride (day of supplementation)					
Item	Day	0	20	30	40	Pr > F	SEM
Visual Color[1]	2	3.35	3.91	3.42	3.80	0.29	0.25
Visual Color	3	3.83	4.37	3.85	4.25	0.56	0.33
Visual Color	4	4.92[b]	5.95[a]	4.88[b]	5.85[a]	< 0.01	0.28
Visual Color	5	6.05	7.03	6.17	7.03	0.02	0.29
Discoloration[2]	2	1.65	2.18	1.75	2.03	0.54	0.29
Discoloration	3	2.56	3.28	2.50	3.27	0.39	0.43
Discoloration	2	3.96	5.81	4.22	5.10	0.06	0.52
Discoloration	2	5.30	6.25	5.70	6.19	0.09	0.30

[1] Visual Color scale: 1 = Very bright red or pinkish red, 2 = Bright red or pinkish red, 3 = Dull red or pinkish red, 4 = Slightly dark red, 5 = Moderately dark red or pinkish red 5.5 = Borderline acceptability to panelist 6 = Dark red or dark reddish tan or dark pinkish red or dark pinkish tan, 7 = Tannish red or tannish pink, 8 = Tan to brown

[2] Surface Discoloration scale: 1 = None (0%) 2 = Slight (1 to 19%) 3 = Small (20 to 39%) 4 = Modest (40 to 59%) 5 = Moderate (60 to 79%) 6 = Extensive (80 to 99%) 7 = Total (100%)

[a,b] Least Squares Means within a row lacking a common superscript letter differ ($P < 0.05$)

LITERATURE CITED

Ahlquist, R. P. 1948. A study of adrenotropic receptors. Amer. J. Physiol. 154: 586.

Allen, P., J.F. Quirke, and P.V. Tarrant. 1987. In β-agonists and their Effects on Animal Growth and Carcass Quality, ed. J.P. Hanrahan. Elsevier Applied Science Publishers, London, p. 83.

Andersen, H. J. and L. H. Skibsted. 1991. Oxidative stability of frozen pork patties. Effect of light and added salt. J. Food Sci. 56(5): 1182-4.

Arnold, R. N., K. K. Scheller, S. C. Arp, S. N. Williams, D. R. Buege, and D. M. Schaefer. 1992. Effect of long- or short-term feeding of alpha-tocopheryl acetate to Holstein and crossbred beef steers on performance, carcass characteristics, and beef color stability. J. Anim. Sci. 70:3055-3065.

Arnold, R. N., S. C. Arp, K. K. Scheller, S. N. Williams, and D. M. Schaefer. 1993. Tissue equilibration and subcellular distribution of vitamin E relative to myoglobin and lipid oxidation in displayed beef. J. Anim. Sci. 71:105-118.

Arthur, P. F., J. A. Archer, D.J. Johnston, R.M. Herd, E.C. Richardson, and P.F. Parnell. 2001. Genetic and phenotypic variance and covariance components for feed intake, feed efficiency, and other postweaning traits in Angus cattle. J. Anim. Sci. 79(11): 2805-2811.

Avendano-Reyes, L., V. Torres-Rodriguez, 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(12): 3259-3265.

Beermann, D.H. 2002. Beta-adrenergic receptor agonist modulation of skeletal growth. J. Anim. Sci. 80:18-23.

Behrends, J. M., W. B. Mikel, C. L. Armstrong, and M. C. Newman. 2003. Color stability of *semitendinosus*, *semimembranosus*, and *biceps femoris* steaks packaged in a high-oxygen modified atmosphere. J. Anim. Sci. 81(9): 2230.

Berge, P., J. Culioli, A. Ouali, and M.F. Parat. 1993. Performance, muscle composition and meat texture in veal calves administered a β-agonist, clenbuterol. Meat Sci. 33(2):191-206.

Berry, B.W., and K.F. Leddy. 1990. Influence of steak temperature at the beginning of broiling on palatability, shear and cooking properties of bean loin steaks differing in marbling. J. Food Qual. 11:159.

Carpenter, C. E., D. P. Cornforth, and D. Whittier. 2001. Consumer preferences for beef color and packaging did not affect eating satisfaction. Meat Sci. 57(4):359-363.

Chan, W. K. M., K. Hakkarainen, C. Faustman, D. M. Schaefer, K. K. Scheller, and Q. Liu. 1996. Dietary vitamin E effect on color stability and sensory assessment of spoilage in three beef muscles. Meat Sci. 42(4):387-399.

Clark, D.S., and C.P Lentz. 1972. Use of carbon dioxide for extending shelf-life of prepackaged beef. Canadian Institute of Food Sci. and Tech J. 6:194–6.

Dawson, J.M., P.J. Buttery, M. Gill and D.E. Beever. 1990. Muscle composition of steers treated with the β-agonist, cimaterol. Meat Sci. 28(4):289-297.

Dikeman, M.E., R.D. Green, and D.M. Wulf. 2003. Effects of Genetics vs Management on Beef Tenderness. Beef Improvement Federation.

Dikeman, M. E. 2007. Effects of metabolic modifiers on carcass traits and meat quality. Meat Sci. 77(1): 121-135.

El-Badawi, A.A., R. F. Cain, C.E. Samuels, and A.F. Anglemeier. 1964. Color and pigment stability of packaged refrigerated beef. Food Tech. 18:7531.

Emery, P.W., N. J. Rothwell, M. J. Stock, and P.D. Winter. 1984. Chronic effects of beta 2-adrenergic agonists on body composition and protein synthesis in the rat. Biosci. Rep. 4:83-91.

Etherton, T.D. and V.K. Meserole. 1982. New technology studied to improve animal growth. Sci. Agr. 29(4):10.

Faustman, C., and R. G. Cassens. 1990. The biochemical basis for discoloration in fresh meat: A review. J. Muscle Foods 1:217.

Faustman, C., W. K. Chan, D. M. Schaefer, and A. Havens. 1998. Beef color update: the role for vitamin E. J. Anim. Sci. 76:1019-1026.

Geesink, G. H., F. J. Smulders, H. L. van Laack, J. H. van der Kolk, T. Wensing, and H. J. Breukink. 1993. Effects on meat quality of the use of clenbuterol in veal calves. J. Anim. Sci. 71(5): 1161-1170.

Gill, C. O. 1996. Extending the storage life of raw chilled meats. Meat Sci. 43(S): 99-109.

Hanrahan, J.P. 1987. *Beta-Agonists and their Effects on Animal Growth and Carcass Quality.* 201 p.

Hood, D.E., and E.B. Riordan. 1973. Discoloration in prepackaged beef: measurement by reflectance spectroscopy and shopper discrimination. J. Food Tech. 8:333-343.

Hood, D. E. 1980. Factors affecting the rate of metmyoglobin accumulation in pre-packaged beef. Meat Sci. 4(4): 247-265.

Hotchkiss, J.H., and D.E. Galloway. 1989. Recip. Meat Conf. Proc., Nat. Live Stock and Meat Board. 31-42.

Huffman, D.L., K.A. Davis, D.N. Marple, and J.A. McGuire. 1975. Effect of gas atmospheres on microbial growth, colour and pH of beef. J. Food Sci. 40:1229–1231.

Insausti, K., M.J. Beriain, A. Perroy, P. Alberti, L. Lizaso, and B. Hernandez. 1999. Colour stability of beef from different Spanish native cattle breeds stored under vacuum and modified atmosphere. Meat Sci. 53(4): 241-9.

Jayasingh, P., D. P. Cornforth, C. P. Brennand, C. E. Carpenter, and D. R. Whittier. 2002. Sensory evaluation of ground beef stored in high-oxygen modified atmosphere packaging. J. Food Sci. 67(9): 3493-6.

Jeremiah, L. E. 1982. Influences of anatomical location and muscle quality on porcine lipid composition. Meat Sci. 7(1): 1-7.

Jeremiah, L. E., A.K.W. Tong, and L.L. Gibson. 1991. The usefulness of muscle color and pH for segregating beef carcasses into tenderness groups. Meat Sci. 30:97-114.

Kropf, D. H. 1980. Effects of retail display conditions on meat color. Proc. Recip. Meat Conf. 33:15-32.

Kropf, D.H. 1982. In: Proc. Int. Symp. Meat Sci. & Tech. 367.

Lanari, M.C., A.E. Bevilacqua, and N.E. Zaritzky. 1989. J. Food Process Eng. 12:49.

Lands, A. M., F. P. Luduena, and H. J. Buzzo. 1967. Differentiation of Receptor Systems activated by Sympathomimetic Amines. Nature. 214(5088): 597-598.

Lawrie. 1991. Editorial. Meat Sci. 2(4): 285-6.

Linn, J. and J. Salfer. 2006. Feed Efficiency. University of Minnesota Extension Service. 1-4.

Liu, Q., M. C. Lanari, D. M. Schaefer. 1995. A review of dietary vitamin E supplementation for improvement of beef quality. J. Anim. Sci. 73(10): 3131-3140.

Liu, Q., K. K. Scheller, S. C. Arp, D. M. Schaefer, and M. Frigg. 1996. Color coordinates for assessment of dietary vitamin E effects on beef color stability. J. Anim. Sci. 74:106-116

Livingston, D. J., & Brown, W. D. 1982. The chemistry of myoglobin and its reactions. Food Tech. 35(5): 244-252.

MacDougall, D. B. 1982. Changes in the color and opacity of meat. Food Chem. 9(1-2) 75-88.

Mancini, R. A., and M. C. Hunt 2005. Current research in meat color. Meat Sci. 71(1): 100-121.

Merkel, R. A. 1988. Is meat quality affected by the use of repartitioning agents? Recip. Meat Conf. Proc. 41:101.

Mersmann, H. J. 1989. Potential mechanisms for repartitioning of growth by β-adrenergic agonists. Animal Growth Regulation. Plenum Publishing Corp., New York. 337-357.

Mersmann, H. J. 1998. Overview of the effects of β-adrenergic receptor agonists on animal growth including mechanisms of action. J. Anim. Sci. 76(1): 160-172.

Milagro, R., N. Batlle, J. L. Navarro, and F. Toldrá. 2004. Stability of β-agonist methyl boronic derivatives before gas chromatography–mass spectrometry analysis. Analytica Chimica. Acta. 529(1-2):293-7.

Mills, S. E. 2002. Biological basis of the ractopamine response. J. Anim. Sci. 80(E-Suppl_2): E28-32.

Moloney, A. P., P. Allen, R. L. Joseph, P. V. Tarrant, and E. M. Convey. 1994. Carcass and meat quality of finishing Friesian steers fed the beta-adrenergic agonist L-644,969. Meat Sci. 38(3): 419- 432.

Muir, L. A. 1988. Effects of beta-adrenergic agonists on growth and carcass characteristics of animals. Animal Production Options in the Marketplace. National Academy Press, Washington, DC. p 184.

NBQA. 2005. www.beefmagazine.com_1-2. Accessed March 28th, 2008.

Reeds, P. J. and H. J. Mersmann 1991. Protein and energy requirements of animals treated with β-adrenergic agonists: a discussion. J. Anim. Sci. 69(4): 1532-1550.

Risvik, E. 1994. Sensory properties and preferences. Meat Sci. 36(1-2): 67-77.

Sami, A. S., C. Augustini, F. J. Schwarz. 2004. Effects of feeding intensity and time on performance, carcass characteristics, and meat quality of simmental bulls. Meat Sci. 67:195-201.

Seyfert, M., R. A. Mancini, M.C. Hunt, J. Tang and C. Faustman. 2007. Influence of carbon monoxide in package atmospheres containing oxygen on colour, reducing activity, and oxygen consumption of five bovine muscles. Meat Sci. 75(3): 432-442.

Sillence, M.N., G. G. and D.B. Lindsay. 1991. Affinity of clenbuterol analogues for β-adrenoceptors in bovine skeletal muscle and the effect of these compounds on urinary nitrogen excretion in female rats. J. Pharmacol. 344:442.

Silliker, J.H., and S.K. Wolfe. 1980. Microbiological safety considerations in controlled atmosphere storage of meats. Food Tech. 34:59–63.

Smith, G. C., K. E. Belk, J. N. Sofos, J.D. Tatum, and S. N. Williams. 2000. Economic implications of improved color stability in beef. Antioxidants in muscle foods: Nutritional strategies to improve quality. New York: Wiley Interscience. 397-426.

Sorheim, O., D.H. Kropf, M.C. Hunt, M.T. Karwoski, and K.E. Warren. 1996. Effects of modified gas atmosphere packaging on pork loin colour, display life and drip loss. Meat Sci. 43:203–212.

Strydom, P.E., E.H. Olser, E. Nel, and K. Leeuw. 2007. The effect of supplementation period of a beta-agonist (zilpaterol hydrochloride) on growth performance, carcass yield and meat quality characteristics. Anim. Nutr. and Anim. Products Inst. 1-4.

Taylor, A.A. and D.B. McDougall. 1973. Fresh beef packages in mixtures of oxygen and carbon dioxide. J. Food Tech. 8:453–461.

USDA. 1997. Official United States standards for grades of carcass beef. Agric. Marketing Serv. Washington, DC.

Van Es, A.J.H. 1977. The energetics of fat deposition during growth. Nutr. Metab. 21:88.

Vestergaard, M., K. Sejrsen, S. Klastrup. 1994. Growth, composition and eating quality of *Longissimus dorsi* from young bulls fed the [beta]-agonist cimaterol at consecutive developmental stages. Meat Sci. 38(1): 55-66.

Wallace, D.H., H.B. Hedrick, R.L. Seward, C.P. Daurio, E.M. Convey. 1987. Growth and efficiency of feed utilization of swine fed a beta-adrenergic agonist, L-644, 969. Beta-agonists and their effects on animal growth and carcass quality. 143-162.

Warriss, P. D., G. R. Nute, T. P. Rolph, S. N. Brown, and S. C. Kestin. 1991. Eating quality of meat from pigs given the beta-adrenergic agonist salbutamol. Meat Sci. 30(1):75-80.

Yang, Y. T., and M.A. McElliot. 1989. Multiple actions of the beta-adrenergic agonists on skeletal muscle and adipose tissue. Biochem. J. 261:1-12.

Young, O. A., A. Priolo, N. J. Simmons and J. West. 1999. Effects of rigor attainment temperature on meat blooming and colour on display. Meat Sci. 52(1): 47-56.

Figure 1:

COLOR SCORING SCALES FOR ZILMAX RESEARCH PROJECT
Multi-university Study 2007 – Use 6 to 8 trained panelists

NAME: ________________________ DATE: ____________________

Initial Color Score Scale: To characterize on the initial appearance

1. Purplish pink or red or reddish tan of vacuum packages
2. Bleached, pale red
3. Slightly cherry red
4. Moderately light cherry red
5. Cherry red
6. Slightly dark red
7. Moderately dark red
8. Dark red
9. Very dark red

*****Score to half-point increments*****

Sample ID	Color Score	Sample ID	Color Score
1		19	
2		20	
3		21	
4		22	
5		23	
6		24	
7		25	
8		26	
9		27	
10		28	
11		29	
12		30	
13		31	
14		32	
15		33	
16		34	
17		35	
18		36	

Figure 2:

COLOR SCORING SCALES FOR ZILMAX RESEARCH PROJECT
Multi-university Study 2007 – Use 6 to 8 trained panelists

NAME: ____________________________ DATE: ______________________

HiOx MAP / LoOx COMAP
Muscle Color Score Scale

1. Very bright red or pinkish red
2. Bright red or pinkish red
3. Dull red or pinkish red
4. Slightly dark red or pinkish red
5. Moderately dark red or pinkish red

Borderline acceptability to panelist

6. Dark red or dark reddish tan or
   Dark pinkish red or dark pinkish tan
7. Tannish red or tannish pink
8. Tan to brown

*****Score to half-point increments*****

Discoloration Scale
Surface % MetMb

1. None (0%)
2. Slight discoloration (1-19%)
3. Small discoloration (20-39%)
4. Modest discoloration (40-59%)
5. Moderate discoloration (60-79%)
6. Extensive discoloration (80-99%)
7. Total discoloration (100%)

*****Whole point increments only*****

Sample ID	Color Score	Discoloration Score	Sample ID	Color Score	Discoloration Score
1			19		
2			20		
3			21		
4			22		
5			23		
6			24		
7			25		
8			26		
9			27		
10			28		
11			29		
12			30		
13			31		
14			32		
15			33		
16			34		
17			35		
18			36		

VITA

Jennifer Green

Candidate for the Degree of

Master of Science

Thesis: EFFECT OF ZILPATEROL HYDROCHLORIDE SUPPLEMENTATION OF BEEF AND DAIRY STEERS ON THE COLOR STABILITY OF TOP SIRLOIN BUTT STEAKS

Major Field: Food Science

Biographical:

Personal Data: Born in Dallas, Texas, on March 20, 1983, the daughter of Ray and Joy Green.

Education: Graduated from Coppell High School in Coppell, Texas in 2001; received bachelor of science degree in Animal Science from Oklahoma State University, Stillwater, Oklahoma in May 2006. Completed the requirements for the Master of Science degree with a major in Food Science at Oklahoma State University in May, 2008.

Experience: Raised in Coppell, Texas with a loving family; employed by VCA as a veterinarian technician during the summers' of 2001 - 2004; employed by Oklahoma State University Center for Veterinary Health Sciences from 2001 – 2006 as barn crew and then an administrative assistant and currently, employed by Oklahoma State University as a graduate teaching assistant, 2006 to 2008.

Professional Memberships: American Meat Science Association, Institute of Food Technologists

Name: Jennifer Nicole Green Date of Degree: May 2008

Institution: Oklahoma State University Location: Stillwater, Oklahoma

Title of Study: EFFECT OF ZILPATEROL HYDROCHLORIDE SUPPLEMENTATION OF BEEF AND DAIRY STEERS ON THE COLOR STABILITY OF TOP SIRLOIN BUTT STEAKS

Pages in Study: 62 Candidate for the Degree of Master of Science

Major Field: Food Science

Scope and Method of Study: The objectives of this study were to evaluate color stability of top sirloin butt steaks from cattle that have been fed a β-agonist, Zilpaterol Hydrochloride, Zilmax®, when placed in either modified atmosphere packages or polyvinylchloride film packages. The current study compared the effects on top sirloin butt steaks fabricated from beef and dairy steers supplemented for 0 d, 20 d, 30 d, or 40 d. One-half of the subprimals were enhanced and three 2.54 cm steaks (d 1, 3, and 5) from each enhanced subprimal were packaged under modified atmosphere packaging (80% O_2 / 20% CO_2). The other half of the subprimals were aged for a total of 21 d and then three 2.54 cm steaks (d 1, 3, and 5) were fabricated from each unenhanced subprimal and packaged under polyvinylchloride (PVC) film packaging. Packages were evaluated for color attributes and discoloration.

Findings and Conclusions: While this study documents that slight differences do exist in color stability in each packaging environment, traditional overwrap and MAP, the differences are not of a magnitude of concern. If recommending a period of supplementation of Zilpaterol Hydrochloride, 20 to 30 d would be suggested to result in, on average, the brightest, reddest steaks possible. Further research could be conducted to further investigate the differences between 20 and 30 d of supplementation and the impact on color.

ADVISER'S APPROVAL: Dr. Deborah Van Overbeke