1-1-2014

The Effect of Feeding Native Warm Season Grasses in the Stocker Phase on the Quality of Beef Loin Steaks

Vikram Pandurang Kurve

The effect of feeding native warm season grasses in the stocker phase on the quality of beef loin steaks

By

Vikram Kurve

A Thesis
Submitted to the Faculty of
Mississippi State University
in Partial Fulfillment of the Requirements
for the Degree of Master of Science
in Food Science and Technology
in the Department of Food Science, Nutrition and Health Promotion

Mississippi State, Mississippi

May 2014

The effect of feeding native warm season grasses in the stocker phase on the quality of beef loin steaks

By

Vikram Kurve

Approved:

_____

M. Wes Schilling
(Director of Thesis)

_____

J. Byron Williams
(Co-Director of Thesis)

_____

Taejo Kim
(Committee Member)

_____

Poulson Joseph
(Committee Member)

_____

Zahur Z. Haque
(Graduate Coordinator)

_____

George M. Hopper
Dean
College of Agriculture and Life Sciences

Name: Vikram Kurve

Date of Degree: May 16, 2014

Institution: Mississippi State University

Major Field: Food Science and Technology

Major Professor: M. Wes Schilling and J. Byron Williams

Title of Study: The effect of feeding native warm season grasses in the stocker phase on the quality of beef loin steaks

Pages in Study: 93

Candidate for Degree of Master of Science

Native Warm Season Grasses (NWSG) provide excellent wildlife habitat and are well adapted to the Southeastern United States. Steaks that were obtained from cattle fed NWSG in the stocker phase and finished on grain and tall fescue were subjected to simulated retail display for 0, 3, 6, and 9 days (grain-finished) and 0, 3, and 6 (forage-finished) days respectively. Grain finished carcasses graded as choice and select while forage finished carcasses were both select and standard. Fat percentage was higher and moisture was lower in steaks from grain finished carcasses when compared to forage finished cattle. Lipid oxidation was lower in forage finished steaks on day 6 (0.35mg malonaldehyde/kg) than grain finished steaks (0.5mg malonaldehyde/kg). The overall acceptability scores given by consumers for both treatment groups were between like slightly and like moderately.

DEDICATION

I would like to dedicate this research to my parents Pandurang Kurve and Priti Kurve, for their immense love and support they have showed towards me.

ACKNOWLEDGEMENTS

I offer profound gratitude to my advisor and mentor Dr. Wes Schilling for believing in me and offering me the opportunity to work under his supervision to start my career in Food Science. Because of your guidance and encouragement, this journey has been most successful. Thank you for being a wonderful person and especially helping whenever it was needed. I am also thankful to Dr. Wes Schilling for reading my rough drafts and making meaningful suggestions. You are the best advisor and mentor a student could have. I would like to thank Dr. Byron Williams for your expertise, valuable suggestions and help towards my research. I am very grateful to Dr. Taejo Kim for giving me permission to use his laboratory and his equipment for my research and helping me understand basic skills in microbiology. You are a very good teacher, I enjoyed every single class you taught. Special thanks to Dr. Poulson Joseph for being my mentor. Without your expertise and suggestions this research would not have been successful. I greatly admire your patience and guidance. Thank you for shaping my career and helping me in my research. I would like to thank my colleagues Sandy, Yan, Monil, Saxon, Austin, and Mike. You are wonderful people and friends. I cherish the time spent with you during my research, and you are the best friends I could ever have in my life. Thank you Monil for helping me with my research and with your help I was able to finish my research in time. I would also like to thank Sandy for all the help you have provided during my research and also mentoring me towards my goal. Thank you Vi Jackson for

helping me with my research. You are a wonderful person, I am very grateful to know you and work with you. I am very thankful to Dr. Kamlesh Soni for his unconditional support and help with my thesis and also helping me obtain an internship. I also appreciate the help of Tim Armstrong and James Cannon in harvesting and fabricating carcasses. I've always enjoyed your company. Special thanks to my friends in Starkville Umang, Vaibhav, Arjun, Peeyush, and Shree, who were there for me when I was feeling the absence of my family. I am also thankful to the wonderful department of Food Science, Nutrition and Health Promotion.

Finally, I would like to thank my parents and my brother Gaurav Kurve and Shital Kurve who are very important people in my life.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER I

INTRODUCTION

Beef is one of the most consumed red meats in the United States (USDA-ERS, 2013). Consumers prefer tender beef with marbling and a cherry red color. Cattle diets and nutrition are important factors that contribute to meat quality (Thomas, et al., 2011). Cattle feeding programs are comprised of three stages that include cow-calf, stocker and finishing phases (Peel, 2011). Feeding grass to cattle is part of the normal physiology in ruminants since they can easily convert grass to muscle (Martin & Rogers, 2004). Cattle are generally fed grass in the stocker phase in the United States as a part of their diet and are finished on grain in feedlots (Thomas, et al., 2011). Grain finishing cattle in feedlots became popular after World-War-II when the demand for beef dramatically increased (Schupp, et al., 1980). In order to meet the increasing demand for beef, producers started finishing beef on grain, which led to increased carcass weight, enhanced marbling and allowed cattle to be harvested and finished in a shorter period of time when compared to grass finishing. Since the 1990s, forage-finished beef has gained popularity among consumers due to perceived health benefits such as healthier fatty acid profiles and a more natural consumer perception. Forage-finished beef has a niche market among consumers who are willing to pay a premium for a beef product from grass-finished cattle (Umberger, et al., 2009).

Beef that is produced from grain finished cattle is generally better quality than beef that is finished on grass. A number of factors are indicators of meat quality such as marbling, color, lipid oxidation, tenderness and juiciness. Beef from grain finished cattle is more red in color (Priolo, et al., 2001) and has a better quality grade, which is partially due to a greater amount of intramuscular fat (Stelzleni & Johnson, 2008) that contributes to consumers liking grain-finished beef more than grass-finished beef (Bowling, et al., 1977, Stelzleni & Johnson, 2008, and Umberger, et al., 2009). However, research also indicates that high quality meat can be produced from forage finished beef when cattle are fed high quality forages with increased crude protein and digestible nutrients (Latimori, et al., 2008 and Realini, et al., 2004). The meat from the cattle which were forage-finished (with a mix of alfalfa and tall fescue) had less lipid oxidation during refrigerated retail display and similar shear values when compared to grain-finished beef. Moreover, fat from grass-finished beef was reported to be more beneficial to human health due to a more balanced n6 to n3 ratio (Daley, et al., 2010 and Duckett, et al., 2009). A greater percentage of polyunsaturated fatty acids were present in the beef muscle cuts (striploin, eye of round, ribeye, top round, tenderloin and top-sirloin) that were produced from grass-finished cattle when compared to grain finished cattle (Pavan & Duckett, 2013).

Native warm season grasses (NWSG) are found in abundance in the Southeastern United States and provide an excellent habitat for wildlife (Harper, 2007). Efforts are being made to conserve these grasses which can also be used as forage for cattle (Hamrick, 2007). Cattle are generally fed bermudagrass in the stocker phase and then finished on grain (Burns, 2011). Feeding bermudagrass resulted in modest average daily

weight gain in the stocker phase, which could potentially be increased through feeding NWSG (Burns, 2011). In the current study, two separate experiments were conducted to analyze the effects of feeding native warm season grasses in cattle diets. The first experiment involved the evaluation of carcass quality, meat quality, and sensory quality of steaks from cattle that were fed either NWSG or bermudagrass in the stocker phase and finished on grain. The second experiment was conducted on cattle that were fed NWSG or bermudagrass in the stocker phase and finished on tall fescue to determine their effects on carcass quality, meat quality, and sensory quality.

CHAPTER II

LITERATURE REVIEW

2.1 Beef Production Systems

The beef production system in the United States consists basically of three phases:1) cow-calf, 2) stocker and 3) finishing operations. In the late 19th century, cattle were mainly fed grass in large fields and finished on forage. During the winter, cattle were kept in barns and fed either hay or silage. Due to increased demand for beef and decreased grain prices, feedlot operations were introduced in the early 20th century to decrease production time. According to Ball and Cornett, (1996), feedlot operations grew at a pace of 20-30% per year from 1961 to 1969 due to decreased grain prices, increased beef yield, and increased consumer demand. Umberger et al. (2003) stated that 20 % of consumers were willing to pay a premium for forage finished beef according to a survey conducted for Argentine forage finished beef and American grain finished beef. Forage is generally fed in the stocker phase in the United States (Galyean, Ponce, & Schutz, 2011). There are numerous varieties of summer and winter forages (Perennial, annual, or crop residues) fed to cattle. Forage finished beef is perceived by consumers as natural and healthier than grain finished beef (Umberger, et al., 2009). Research indicates that forage finished beef has a different fatty acid composition than grain finished beef which may be more beneficial to human health (Daley, et al., 2010). Sustainable beef production is

gaining momentum as the use of fossil fuels for production is increasing rapidly, which is a growing concern to environmentalists (Peel, 2011).

Bermudagrass is commonly used to feed cattle in the stocker phase in the summer months in the mid-Atlantic and Southeastern United States (Burns, 2011). Bermudagrass has contributed to decreasing forage availability in these areas. However, moderate weight gains have been reported with the use of bermudagrass (Burns, 2011). To improve weight gain from forage, varieties of bermudagrass (Tifton 44 and Tifton 85) have been introduced into the region. Since these grasses are dependent on nitrogen inputs and lead to modest average daily weight gains, there is an opportunity to explore other sources of forage for use in feeding cattle. Perennial grasses in these regions are very important for the production of cattle since cool season grasses are dormant during the summer months. During stress, drought and winter, grasses that provide pasture during the summer months are conserved as forage in the form of hay or silage.

Native warm season grasses (NWSG) in the Southeastern United States are an alternative to bermudagrass for grazing cattle. Forage systems in the South include 24 million ha of perennial forages and 8 million ha of annual forages (Ball, et al., 2007). In Mississippi, NWSG is being evaluated for use as pasture since it is an excellent habitat for wildlife and these grasses have been overtaken by non-native forage such as bermudagrass (Hamrick, 2007). Native warm season grasses such as switch grass, little bluestem, big bluestem and Indiangrass are being studied extensively for different uses. NWSG is an excellent wildlife habitat, can be used as a biofuel, and can be used as forage (Hamrick, 2007). These grasses are not dense and therefore provide more space than bermudagrass for bird species (Hamrick, 2007). There is an abundant growth of

NWSG in the Southeastern United States, which can be used as an alternative to bermudagrass for feeding cattle due to large expanses of pasture land that can be managed through rotational grazing (Burns & Fisher, 2012). According to Hamrick (2007), the average daily weight gains from native warm season grasses can be comparable or even greater than when bermudagrass is used. Greater average daily weight gains and forage yield would be beneficial to farmers that raise cattle. Burns and Fisher (2012) also looked for the ability of NWSG to be converted to hay and baleage for use in winter due to limited forage availability and found that these grasses are easy to establish and are readily consumed by cattle. The average daily weight gain reported by Burns and Fisher (2012), when bermudagrass was compared with four varieties of NWSG, resulted in better weight gain in NWSG compared to bermudagrass. The average daily weight gain for bermudagrass was 0.49 kg and 0.73 kg for NWSG.

Meat quality is commonly determined by evaluating flavor, texture, color, lipid oxidation, lipid content, lipid composition, and uniformity (Andersen, et al., 2005). Meat quality is a result of production, management, genetics, harvesting, and storage conditions. Vestergaard et al. (2000) reported that finishing cattle on forage increased muscle glycogen concentration when compared to grain finished beef. Muscle glycogen is an important factor in determining meat quality and is correlated to color, cook loss and tenderness (Lahucky, et al., 1998). The acceptance of forage finished beef among consumers solely depends upon the appearance and flavor of the meat. Finishing cattle on forage produced smaller carcasses with less fat and muscle (Kerth, et al., 2007). Since forage finished cattle produces beef which is lean, has a darker color, and potentially has off-flavors, many consumers in the United States prefer grain finished beef over forage

finished beef (Kerth, et al., 2007). Research has shown that finishing cattle on forages can produce beef that is similar in tenderness and juiciness with a greater ratio of n:3 to n:6 fatty acids when compared to cattle finished on grain (Scaglia, et al., 2012, and Duckett, et al., 2007). Latimori et al. (2008) indicated that there were no differences in tenderness and color values when cattle were finished on forages or grain. Cox et al. (2006) reported that one third to one half of the population in the southern United States liked forage finished beef and concluded in his research that finishing cattle on forages could be an alternative source of finishing cattle in comparison to grain finishing in feedlots. Similarly, Scaglia et al. (2012) reported that the niche market in the United States for forage finished beef is increasing in size and is a potential alternative to grain finished beef. There are opportunities in the southeastern United States to produce cattle that are fed different forages in the stocker phase. The extrinsic quality attributes of meat products, such as product brands, geographic origin, production information, and packaging are important to some consumers (Bernues, et al., 2003). The purchasing decision is most often based on color and marbling. However, forage finished beef has less marbling and is slightly darker in color which leads to decreased consumer acceptance of grass finished beef. McCluskey et al. (2005) discussed the health benefits of forage finished beef and suggested that consumer preference is more important to the beef industry than the perceived health benefits of forage finished beef.

2.2 Carcass Quality

Beef quality is initially (post harvesting) measured in terms of USDA Quality grades (USDA, 1997). Physiological maturity and marbling are the two main factors that determine the quality grade of a beef carcass. There are eight quality grade designations:

Prime, Choice, Select, Standard, Commercial, Utility, Cutter and Canner. USDA yield grade is the estimate of beef carcass cutability which refers to the amount of lean edible boneless meat from the carcass. Carcasses with high quality grades often have lower yield grades. Actual fat thickness, adjusted fat thickness, *longissimus* muscle area, kidney, pelvic, and heart fat percentage are the factors which are evaluated and used to determine the yield grade of beef carcasses. According to USDA standards, a yield grade 1 carcass will have the highest percentage of lean meat cuts and a yield grade 5 carcass will have the lowest percentage of lean meat cuts. In addition, yield grade is not typically used by consumers as a selection criterion for making purchasing decisions at retail stores. Bidner et al. (1981) & Bowling et al. (1977) reported that frame size and finishing systems affect carcass quality. Generally, carcasses from forage finished beef are leaner with less marbling and have lighter hot carcass weights (HCW) when compared to grain finished beef which have higher HCWs and more intramuscular fat. Kerth et al. (2007) reported that carcasses from cattle finished on rye grass had less marbling than carcasses from grain finished cattle. Grain finished cattle yielded better carcass quality and grass finished cattle yielded smaller carcasses with less marbling and muscling. These researchers suggested that finishing cattle to a common end point (2.54 cm back-fat) can reduce the marbling differences between forage and grain finished cattle, but with increased grazing periods in grass finished cattle, it can affect color attributes with darker meat color and increased warner-bratzler shear force values. USDA quality grades are used to predict the palatability of meat from a beef carcass and are predominantly associated with the amount of marbling in the meat.

2.3 pH

Normal muscle pH in cattle is 7.0-7.2. After slaughter, the muscle pH decreases to between 5.5 and 5.8 after rigor mortis is complete and the muscle has been converted to meat (Nollet & Toldra, 2010). The decline in postmortem pH is related to the amount of muscle glycogen present. At a higher pH, more water is trapped within myofibrillar proteins, resulting in less free water to reflect light. Therefore, muscle from forage-finished cattle will appear darker than that of grain-finished cattle. Campo et al. (2006), French et al. (2000), Maughan et al. (2012), and Nuernberg et al. (2005) reported that beef (*longissimus* muscle) from grass-finished steers had higher ultimate pH values than grain-finished steers and suggested that grass-finished steers were more susceptible to pre-slaughter stress than grain-finished steers. Lower muscle pH is associated with beef that is redder and more yellow, whereas higher muscle pH is associated with beef that is greener and more blue (Page, et al., 2001). Muir et al. (1998) and Nuernberg et al. (2005) reported that forage-finished cattle had higher ultimate pH values than grain-finished cattle which can be related to the pre-slaughter glycogen depletion in grass finished steers. Some studies reported no differences in ultimate pH for beef that were finished on grass and/or grains (French, et al., 2000 and Razminowicz, et al., 2006). The higher ultimate pH for forage finished beef in some studies is attributed to long term ante-mortem stress which is due to the lack of being accustomed to penning and handling whereas grain finished steers are more accustomed to penning and handling (less stress) and also have increased levels of glycogen stored in their muscles.

2.4 Proximate Composition

The chemical composition of beef is influenced by many factors, such as breed, age, finishing systems, and pre-slaughter stress. Production systems impact the chemical composition of the resulting meat which impacts the eating quality of the beef. Forage finished cattle produces beef that is lean with less fat when compared to grain-finished beef, with 4-5 % intramuscular fat in grain finished cattle and between 2-3 % intramuscular fat in grass finished beef (Leheska, et al., 2008). Forage finished beef is associated with n:3 fatty acids that are beneficial to human health due to of the high amount of poly-unsaturated fatty acids. French et al. (2000) did not observe any differences between treatments for fat, protein and moisture when cattle were finished on grass silage, grass or concentrate based diets. In a study conducted by Duckett et al. (2009), results indicated that when cattle were finished on a concentrate diet, fat percentage was greater but moisture was less in the *longissimus* muscle when compared to beef from forage finishing systems, but the protein concentration did not differ in beef from grain and forage finishing systems. Leheska et al. (2008) studied the effects of conventional and grass feeding on the composition of beef and found that grass finished beef had less fat (2.8 % total fat) than grain finished (4.3 % total fat in strip loin steaks) and that the fat from grass finished steers was yellow. Collagen content of beef (*longissimus* muscle) from a forage based finishing system was greater than that in beef from grain finished cattle (Duckett, et al., 2007).

2.5 Color

The appearance attributes of beef steaks, including color and marbling, greatly impacts the purchasing decisions of consumers (Umberger, et al., 2009). The eating

quality of meat is determined by several factors such as lipid oxidation, pH, microbiological deterioration and fatty acid composition. However, color is an important attribute since consumers use appearance as their primary determinant when purchasing meat and meat products. Instrumental color is measured through the use of a colorimeter as an indicator of meat quality. Beef color is commonly evaluated through CIE L* a* b*, hue and, chroma. For discoloration in meat products, hue angle and saturation index is used to detect differences. Hue distinguishes the color between red, blue and green and chroma is a measurement of color intensity. These measurements are used as an indicator of color defects in meat and meat products and are related to the state of myoglobin present in the muscle. Instrumental color measurements are based on the principle of light reflectance at different wavelengths. Priolo et al. (2001), Stelzleni & Johnson, (2008), and Yang et al. (2002) have reported that color of beef from cattle that are finished on grain is much better than grass finished beef because it is more cherry red and lighter in color. Use of additives in feed is one approach to enhance the color of meat. Incorporation of vitamin E in the diet (Yang, et al., 2002) of cattle that were finished on grass or grain was determined to improve the color values (CIE L*; lightness and a*; redness) of beef steaks. Grain finished beef was redder and lighter than grass finished beef. Vitamin E supplementation did not enhance the color of grass finished beef. However, color differences in both the feeding treatments were not appreciable when aged for 4-7 days. On the contrary, Bloomberg et al. (2011) evaluated the effect of vitamin E inclusion in cattle diets with wet distillers grain that were grain-finished on the color stability and consumer acceptability of steaks. Ground samples exhibited less color differences between treatments. However, for steaks, a greater inclusion of vitamin E

(250 and 500 IU) in diets maintained redness and yellowness (till six days in retail display) of steaks when compared to animals that received less vitamin E in their diets (started to show discoloration at five days display in PVC packaging). The role of vitamin E and other naturally occurring compounds in grass (antioxidant vitamins, a-tocopherol and b-carotene) were evaluated for their contribution to the yellow color (Insani, et al., 2008). Redness values were greater in steaks from cattle fed and finished on forage diets and lightness was lower when compared to steaks from grain finished cattle. The results indicated that higher levels of vitamin E in the cattle's diet that were grass finished maintained the redness of steaks. Supplementation or restriction of vitamin A in diets of cattle was evaluated by Daniel et al. (2009). Cattle were either restricted or supplemented with vitamin A during finishing. Lightness, redness and saturation index values were less in steaks that were supplemented with vitamin A when compared to those without vitamin A in the diet. Therefore, vitamin A supplementation in the diet of cattle enhanced the color of grain-finished beef.

The effect of lactate addition on the color of *longissimus* muscle was determined in combination with different packaging systems (Mancini, et al., 2009). The addition of lactate to beef steaks enhanced the redness of steaks that were packaged in high oxygen. Use of lactate had darkening issues in vacuum packaged systems when compared to CO and high-oxygen packaging systems. Color stability in the CO packaging was better than that it was in high-oxygen in terms of redness (a* values). Packaging systems have controlled atmosphere inside which helps enhance and/or prolong shelf life by preventing discoloration. Use of different packaging systems was demonstrated by Grobbel et al. (2008), in which high-oxygen MAP, ultra-low oxygen MAP and vacuum packaging were

evaluated for their effect on the color of beef steaks that were stored in the dark and under fluorescent lighting. Color values indicated that ultra-low oxygen packaging enhanced and maintained the redness of fresh steaks due to the CO in the packaging systems, whereas high oxygen MAP packaging contributed to premature browning which is correlated to myoglobin oxidation. Steaks that were packaged under vacuum had minimal discoloration. High oxygen MAP led to the color deterioration of steaks 56 percent more rapidly than the other packaging systems.

2.6 Thiobarbituric Acid Reactive Substances

During refrigerated and frozen storage, lipids and proteins can oxidize in beef steaks and other beef products. Grazing, slaughtering, packaging and inclusion of antioxidants have been investigated to determine their effects on lipid and color oxidation. Oxidation of unsaturated fatty acids that are present in the meat can lead to undesirable rancid off-flavors in the meat. The process of oxidation can be catalyzed by pre and post harvesting factors such as handling, processing, and storage (Chaijan, 2008). Lipid oxidation can also be initiated by myoglobin oxidation, which results in the brownish discoloration of meat (Baron & Andersen, 2002). Oxidation products of polyunsaturated fatty acids in beef include aldehydes, ketones, and hydroxides. These are the secondary products of lipid oxidation which are responsible for rancidity and off-flavors in meat (Faustman, et al., 2010). Wood et al. (2004) reported that muscles with greater proportions of red fibers are more susceptible to oxidation due to a higher concentration of phospholipids and iron. In addition, ground meat is more susceptible to lipid oxidation since it has more surface area and comes in contact with air and metal during grinding. It appears that forage finished animals tend to produce product that is

less susceptible to lipid oxidation during storage whereas animals fed grain diets seem to initially have better color that deteriorates rapidly during subsequent storage (Yang, et al., 2002). In one such study, psoas major steaks from grain and forage finished cattle were compared and the first evidence of lipid oxidation occurred within 3 days for grain finished animals whereas this time duration was 7 days for forage finished animals (Insani, et al., 2008). The limited lipid oxidation in forage finished animals was correlated to a higher abundance of a-tocopherol. Yang et al. (2002) reported that the incorporation of vitamin E fortified grain or pasture diet did not provide any protection against lipid oxidation in comparison to non-fortified diets. The grain finished animals had better initial color when compared to grass finished animals. However, this color difference dissipated after storage under retail lights. Since grass finished animals contain higher concentrations of PUFA, which are known to adversely affect meat color and lipid stability, it has been proposed that higher concentrations of a-tocopherol in grass finished diets counteract the potential for oxidation of PUFA (Yang, et al., 2002). There has been research conducted in which different levels of PUFA in the diets of cattle were included to determine their effect on meat quality (Campo, et al., 2006). The diets which were high in either saturated fatty acids or vitamin E produced beef with less lipid oxidation than diets that had higher concentrations of PUFA. One study investigated the effect of incorporating vitamin A in the diets of cattle that were weaned at different times (Daniel, et al., 2009). Carcass yield and quality grade, color stability, lipid oxidation and consumer acceptability were evaluated for the beef steaks and ground meat that were packaged in PVC and MAP and subjected to retail display for 7 days. Steak quality was evaluated on day 7 of storage for PVC packaging and at 1, 3 and 7 days for MAP

packaging, and 0 and 7 days of retail display for ground beef with PVC and MAP packaging. Results indicated that strip loin steaks with inclusion (250 and 500 IU) of vitamin E in the diet had less lipid oxidation (2.28 mg of malonaldehyde/kg) after 7 days of storage when compared to the control (3.1 mg of malonaldehyde/kg). Inclusion of vitamin E had a greater effect on meat quality when it was included at a higher concentration; these natural antioxidants are present in grass which is why cattle fed on high quality forages may produce beef that has less lipid oxidation than beef from grain finished cattle.

Resconi et al. (2012) conducted research to understand how varying levels of oxygen content (50, 60 and 80%) in MAP affect lipid oxidation. The higher oxygen levels did not impact rancidity. For example, MAP with 50% oxygen had the lowest color stability. TBARS values after 4 days of retail display for 50%, 60% and 80% oxygen MAP packaged steaks were 1.30, 1.44 and 0.75, respectively. Similarly, after 8 days of display the tbars values were 2.80, 3.13 and 2.27, respectively. In another study, oxygen levels between 20 and 80% were evaluated, and it was concluded that between 55 and 80% oxygen in MAP were ideal for maintaining desirable meat color.

Packaging with antioxidants can have a positive effect on the shelf life of meat and meat products that would otherwise have off-flavors that are end products of lipid oxidation. These antioxidants are generally used in processed meat products rather than fresh meats since the former is more susceptible to lipid oxidation since they have a longer shelf life. Antioxidants like free radical scavengers, chelators and reductants have been used (Faustman & Cassens, 2007). Meat products have been fortified with chelators (sodium tripolyphosphate, sodium citrate and CIT), reductants (sodium erythorbate and

ERY) and radical scavengers (butylhydroxyamisole, BHA and tocopherols mixed) and n-3 fatty acids to maintain the meat quality with respect to color and lipid oxidation. The combination of CIT and ERY was able to maintain redness and inhibit lipid oxidation during storage in PVC packaging. Suman et al. (2010) evaluated the color and lipid oxidation of ground beef with chitosan that were stored under vacuum, modified atmosphere with carbon monoxide and aerobic packaging at 1°C. Ground beef patties that contained chitosan had less lipid oxidation in all packaging systems during retail display when compared to the control.

2.7 Microbial Spoilage

Microbial quality depends on processing, handling, pH, packaging and storage temperature. Microbial development leads to changes in meat quality and formation of degradation products that decrease freshness (Ercolini, et al., 2006). Microbial spoilage is indicated by the formation of off-odor, discoloration, slime formation and changes in physical appearance of the meat, which makes it unacceptable to consumers (Gram, et al., 2002).

2.8 Warner-Bratzler Shear Force and Cook Loss

Beef that has been produced from forage-finished cattle tends to have higher shear values, which indicates that it is tougher than grain finished beef. Forage finished beef in general is tougher than grain finished beef due to those animals requiring greater time on feed to attain weight which results in the formation of more connective tissue. Grain finished beef is also usually more tender because of the fat cover which prevents meat from cold shortening (Bidner, 1981). With good quality forage (higher crude protein and

better digestible nutrients) and great management, some researchers were able to minimize differences between the beef finished on forage or grain. Most tenderness evaluations have been performed on the *longissimus* muscle (Pavan & Duckett, 2013). The amount of marbling also affects the tenderness of beef cuts. Choice *longissimus* steaks had lower shear values than select grade beef *longissimus* muscle even after 28 days of aging (Gruber, et al., 2006). Koohmaraie et al. (2002) stated that the tenderization process in muscle starts after slaughter as a result of proteolysis of myofibrillar proteins. Duckett et al. (2007) did not find any difference in shear force between steaks from forage finished and grain finished beef and attributed this result to harvesting of cattle at the same endpoint for both finishing systems. Similar values were reported by Mandell et al. (1998) and Realini et al. (2004). These authors reported no difference in the warner-bratzler shear force values between forage and grain finished beef.

Cooking loss is another quality trait which is not directly related to consumer purchasing decisions but impacts quality in terms of moisture and fat loss. Meat with similar lipid content or marbling has similar cook loss (Kerth, et al., 2007). Sawyer et al. (2008) found that meat with high ultimate pH (higher than pH of 5.5 to 5.7 after 24 h postmortem in beef) had less cook loss than meat with normal pH (5.5-5.8). Bowling et al. (1977) found no differences in cook loss for loin steaks from cattle finished on grain or grass. Bruce et al. (2004) reported higher cooking loss in steaks from grain finished cattle and attributed it to the higher lipid content in *longissimus* steak from grain finished cattle.

2.9 Fatty Acid Profile

Generally meat from ruminants is low in polyunsaturated fatty acids (PUFA) when compared to saturated fatty acids (SFA). This low PUFA to SFA ratio in ruminants is because of the ruminal biohydrogenation of dietary unsaturated fatty acids. The most common fatty acids in beef are oleic (C18:1), palmitic (C16:0), and stearic (C18:0) (Realini, et al., 2004). Saturated fats from beef are regarded as unhealthy for the human diet since saturated fats raise total blood cholesterol level and contribute to heart disease (Pavan & Duckett, 2013). Fincham et al. (2009) reported that as time on feed increased, the percentage of C18:3 n-3 fatty acids increased in steaks from forage-finished cattle, and the amounts of the same fatty acid decreased (1.96 for grain finished compared to 2.63 for forage finished at 140 days of feeding) in steaks from grain finished cattle. Forage finished beef is considered to be rich in omega-3 and omega-6 fatty acids which are also important since these fatty acids cannot be manufactured by the human body. Duckett et al. (2009) reported that there were higher concentrations of myristic and palmitic acid in grain finished beef when compared to forage finished beef and a higher concentration of stearic acid (C18:0) for forage finished beef. Daley et al. (2010) suggests that not all SFA's have a greater impact on human health than other fatty acids. Lauric acid and myristic acid have greater cholesterol raising effects while stearic acid and palmitic acid had no net impact on serum cholesterol levels in the human body (Williamson, et al., 2005). Finishing diet significantly alters the fatty acid composition of beef, but other factors such as breed and age also impact fatty acid composition (Scollan, et al., 2005). Daley et al. (2010) reviewed the literature for fatty acid profiles in grass finished beef and found that grass finished beef has less total lipid content when

compared to grain finished beef. In their review, stearic acid concentration was greater in grass finished beef. The total cholesterol levels in grass finished beef was lower (40.3 grams of cholesterol per 100 grams) than grain finished (45.8 grams of cholesterol per 100 grams) which is related to the overall lipid content (Garcia, et al., 2008). Apart from the health benefits from less fat, grass finished beef also had higher concentrations of n-3 fatty acids which are categorized as polyunsaturated fatty acids (PUFA). The ratio of n-6 to n-3 is important to the human diet and relates to cardiovascular disease since its risk is lowered by the intake of n-3 fatty acids. The important fatty acids in red meat are alpha linolenic acid (omega-3) and linoleic acid (omega-6) which are essential for the human body since they are not synthesized in the body. Grass finished cattle produce beef with more omega-3 fatty acids and a similar omega-6 fatty acid percentage when compared to grain finished beef (Daley, et al., 2010 and Razminowicz, et al., 2006). This ratio is favorable for human health since it has been shown that as grain percentage in the diet increases, omega-3 concentration in the meat decreases. Conjugated linoleic acids (CLA) are another group of fatty acids that are present in the meat of ruminants and are important in the human body since CLA has been shown to contribute to reduced incidence of carcinogenesis, atherosclerosis and diabetes. Also, the antioxidant properties of grass finished beef increases which make it more stable for lipid oxidation and discoloration (Yang, et al., 2002). Because of health concerns regarding the consumption of meats, consumers are interested in knowing the health benefits from grass/forage finished beef (Pavan & Duckett, 2013). Razminowicz et al. (2006) reported similar health benefits from grass finished beef as mentioned previously in this section and reported that

termination of grass feeding in the winter rapidly decreased the n-3 fatty acid stores in the muscles.

2.10 Sensory Analyses

The sensory properties of forage and grain finished beef have been researched extensively. Many studies have indicated that beef produced from grass finished cattle have off-flavors, is less tender, has lower quality grades, has yellow fat and dark colored lean meat when compared to grain finished beef. However, some recent research has shown that forage finished beef can be produced with similar characteristics to grain finished beef (Cox, et al., 2006 and Kerth, et al., 2007). Finishing cattle on grass to the same endpoint as grain finished beef has led to better flavor and texture quality in grass-finished beef. Priolo et al. (2001) reported that consumer's perception of red meat is skewed towards grain finished meat since forage finished beef has been associated with off-flavors. The most intense flavors described for forage finished beef are grassy and barny (Priolo, et al., 2001). Sitz et al. (2005) reported that consumer's preferred domestic beef that was finished on conventional grain as compared to Australian grass finished beef. Even when there were no differences in tenderness and slight differences in quality grades, consumers favored domestic beef because of flavor. Consumers indicated that there were off-flavors and off-odors in the Australian grass finished beef which was related to lipid oxidation. Killinger et al. (2004) also reported that consumers preferred domestic beef that was conventionally produced in the United States to Argentine grass finished beef with similar marbling and shear force values. In most of the studies conducted on sensory or eating quality of beef, intramuscular fat was related to the flavor, juiciness and tenderness of beef. Grain finished beef has more intramuscular fat and

therefore is perceived by consumers as having better flavor than forage finished beef which is lean and darker in color. Similar results were reported by Leick et al. (2012) where consumer preferences were based on steak thickness, color and marbling. Maughan et al. (2012) developed a flavor lexicon to describe the various flavor attributes found in beef. They found that the flavor associated with grassy, gamey, livery and metallic were considered off-flavors and negatively impacted consumer perception. While flavors such as brothy, umami, juicy, browned, fatty and salty positively impacted consumer perception. Negatively perceived flavors were more intense and more prevalent in grass finished beef. Grass finished beef was also less juicy and umami flavor intensity. Whereas, grain finished beef had greater intensity and prevalence of positive flavors. The consumer panels indicated preference of grain finished beef with scores averaging 7.1 (moderately liked) over grass finished beef scoring 6.1 (slightly liked) on a nine point hedonic scale. This preference for grain finished beef among consumers was related to the off-flavors associated with grass finished beef. The quality grade of beef steaks was an important factor in consumer preference when USDA choice steaks were compared with forage finished and USDA select steaks (Baublits, et al., 2006). The grassy flavor in beef is associated with hexanal, which is derived from oleic and alpha linoleic acid. Since the fatty acid profile in grass finished and grain finished beef is different, the flavor profile is likely to change as the breakdown of fatty acids impart flavor to the meat (Bowling, et al., 1977).

2.11 References

Andersen, H. J., Oksbjerg, N., Young, J. F., & Therkildsen, M. (2005). Feeding and meat quality–a future approach. *Meat Science, 70*(3), 543-554.

Ball, D., Hoveland, C.S., & Lacey, G.D. (2007). Southern forages, modern concept for forage crop management. 4th ed., *International Plant Nutrition Inststitute*, Norcross, GA.

Baron, C. P., & Andersen, H. J. (2002). Myoglobin-induced lipid oxidation. A review. *Journal of Agricultural and Food Chemistry, 50*(14), 3887-3897.

Baublits, R., Brown Jr, A., Pohlman, F., Rule, D., Johnson, Z., Onks, D., Murrieta, C., Richards, C., Loveday, H., & Sandelin, B. (2006). Fatty acid and sensory characteristics of beef from three biological types of cattle grazing cool-season forages supplemented with soyhulls. *Meat Science, 72*(1), 100-107.

Bernués, A., Olaizola, A., & Corcoran, K. (2003). Extrinsic attributes of red meat as indicators of quality in Europe: an application for market segmentation. *Food Quality and Preference, 14*(4), 265-276.

Bidner, T. D., Schupp, A. R., Montgomery, R. E., &, Carpenter Jr, J. C. (1981). Acceptability of beef finished on all-forage, forage-plus grain or high energy diets. *Journal of Animal Science, 62,* 381–387.

Bloomberg, B., Hilton, G., Hanger, K., Richards, C., Morgan, J., & VanOverbeke, D. (2011). Effects of vitamin E on color stability and palatability of strip loin steaks from cattle fed distillers grains. *Journal of Animal Science, 89*(11), 3769-3782.

Bowling, R., Smith, G., Carpenter, Z., Dutson, T., & Oliver, W. (1977). Comparison of forage-finished and grain-finished beef carcasses. *Journal of Animal Science, 45*(2), 209-215.

Bruce, H., Stark, J., & Beilken, S. (2004). The effects of finishing diet and postmortem ageing on the eating quality of the M. longissimus thoracis of electrically stimulated Brahman steer carcasses. *Meat Science, 67*(2), 261-268.

Burns, J. (2011). Intake and digestibility among Caucasian bluestem, big bluestem, and switchgrass compared with bermudagrass. *Crop Science, 51*(5), 2262-2275.

Burns, J., & Fisher, D. (2012). Intake and digestibility of big bluestem hay and baleage. *Crop Science, 52*(5), 2413-2420.

Campo, M., Nute, G., Hughes, S., Enser, M., Wood, J., & Richardson, R. (2006). Flavour perception of oxidation in beef. *Meat Science, 72*(2), 303-311.

Chaijan, M. (2008). Review: Lipid and myoglobin oxidations in muscle foods. *Songklanakarin. Journal of Science and Technolgy, 30*, 47-53.

Cox, R. B., Kerth, C. R., Gentry, J. G., Prevatt, J. W., Braden, K. W., & Jones, W. R. (2006). Determining acceptance of domestic forage-or grain-finished beef by consumers from three southeastern US states. *Journal of food science, 71*(7), S542-S546.

Daley, C. A., Abbott, A., Doyle, P. S., Nader, G. A., & Larson, S. (2010). A review of fatty acid profiles and antioxidant content in grass-fed and grain-fed beef. *Nutrition Journal, 9*(1), 10.

Daniel, M., Dikeman, M., Arnett, A., & Hunt, M. (2009). Effects of dietary vitamin A restriction during finishing on color display life, lipid oxidation, and sensory traits of longissimus and triceps brachii steaks from early and traditionally weaned steers. *Meat Science, 81*(1), 15-21.

Duckett, S., Neel, J., Fontenot, J., & Clapham, W. (2009). Effects of winter stocker growth rate and finishing system on: III. Tissue proximate, fatty acid, vitamin, and cholesterol content. *Journal of Animal Science, 87*(9), 2961-2970.

Duckett, S. K., Neel, J. P. S., Sonon Jr, R. N., Fontenot, J. P., Clapham, W. M., & Scaglia, G. (2007). Effects of winter stocker growth rate and finishing system on: II. Ninth-tenth-eleventh-rib composition, muscle color, and palatability. *Journal of Animal Science, 85*(10), 2691-2698.

Dunne, P. G., Monahan, F. J., O'Mara, F. P., & Moloney, A. P. (2005). Colour stability, under simulated retail display conditions, of M. longissimus dorsi and M. semimembranosus from steers given long-term daily exercise and supplemented with vitamin E. *Meat Science, 71*(3), 480-489.

Ercolini, D., Russo, F., Torrieri, E., Masi, P., & Villani, F. (2006). Changes in the spoilage-related microbiota of beef during refrigerated storage under different packaging conditions. *Applied and Environmental Microbiology, 72*(7), 4663-4671.

Faustman, C., & Cassens, R. (2007). The biochemical basis for discoloration in fresh meat: A review. *Journal of Muscle Foods, 1*(3), 217-243.

Faustman, C., Sun, Q., Mancini, R., & Suman, S. P. (2010). Myoglobin and lipid oxidation interactions: Mechanistic bases and control. *Meat Science, 86*(1), 86-94.

Fincham, J., Fontenot, J., Swecker, W., Herbein, J., Neel, J., Scaglia, G., Clapham, W., & Notter, D. (2009). Fatty acid metabolism and deposition in subcutaneous adipose tissue of pasture-and feedlot-finished cattle. *Journal of Animal Science, 87*(10), 3259-3277.

French, P., O'Riordan, E. G., Monahan, F. J., Caffrey, P. J., Vidal, M., Mooney, M. T., Troy, D. J., & Moloney, A. P. (2000). Meat quality of steers finished on autumn grass, grass silage or concentrate-based diets. *Meat Science, 56*(2), 173-180.

Galyean, M. L., Ponce, C., & Schutz, J. (2011). The future of beef production in North America. *Animal Frontiers, 1*(2), 29-36.

Garcia, P., Pensel, N., Sancho, A., Latimori, N., Kloster, A., Amigone, M., & Casal, J. (2008). Beef lipids in relation to animal breed and nutrition in Argentina. *Meat Science, 79*(3), 500-508.

Gram, L., Ravn, L., Rasch, M., Bruhn, J. B., Christensen, A. B., & Givskov, M. (2002). Food spoilage—interactions between food spoilage bacteria. *International Journal of Food Microbiology, 78*(1), 79-97.

Grobbel, J., Dikeman, M., Hunt, M., & Milliken, G. (2008). Effects of packaging atmospheres on beef instrumental tenderness, fresh color stability, and internal cooked color. *Journal of Animal Science, 86*(5), 1191-1199.

Gruber, S., Tatum, J., Scanga, J., Chapman, P., Smith, G., & Belk, K. (2006). Effects of postmortem aging and USDA quality grade on Warner-Bratzler shear force values of seventeen individual beef muscles. *Journal of Animal Science, 84*(12), 3387-3396.

Hamrick, R., Burger,W. L., Jones, J., & Striddand, B. (2007). Native warm-season grass restoration in Mississippi. *Mississippi State University Extension Service*. *http://msucares.com/pubs/publications/p2435.pdf*.

Insani, E. M., Eyherabide, A., Grigioni, G., Sancho, A. M., Pensel, N. A., & Descalzo, A. M. (2008). Oxidative stability and its relationship with natural antioxidants during refrigerated retail display of beef produced in Argentina. *Meat Science, 79*(3), 444-452.

Kerth, C. R., Braden, K. W., Cox, R., Kerth, L. K., & Rankins Jr, D. L. (2007). Carcass, sensory, fat color, and consumer acceptance characteristics of Angus-cross steers finished on ryegrass (Lolium multiflorum) forage or on a high-concentrate diet. *Meat Science, 75*(2), 324-331.

Killinger, K. M., Calkins, C. R., Umberger, W. J., Feuz, D. M., & Eskridge, K. M. (2004). Consumer sensory acceptance and value for beef steaks of similar tenderness, but differing in marbling level. *Journal of Animal Science, 82*(11), 3294-3301.

Koohmaraie, M., Kent, M. P., Shackelford, S. D., Veiseth, E., & Wheeler, T. L. (2002). Meat tenderness and muscle growth: Is there any relationship? *Meat Science, 62*(3), 345-352.

Lahucky, R., Palanska, O., Mojto, J., Zaujec, K., & Huba, J. (1998). Effect of preslaughter handling on muscle glycogen level and selected meat quality traits in beef. *Meat Science, 50*(3), 389-393.

Latimori, N., Kloster, A., Garcia, P., Carduza, F., Grigioni, G., & Pensel, N. (2008). Diet and genotype effects on the quality index of beef produced in the Argentine Pampeana region. *Meat Science, 79*(3), 463-469.

Leick, C., Behrends, J., Schmidt, T., & Schilling, M. (2012). Impact of price and thickness on consumer selection of ribeye, sirloin, and top loin steaks. *Meat Science, 91*(1), 8-13.

Mancini, R. A., Suman, S. P., Konda, M. K. R., & Ramanathan, R. (2009). Effect of carbon monoxide packaging and lactate enhancement on the color stability of beef steaks stored at 1°C for 9 days. *Meat Science, 81*(1), 71-76.

Mandell, I., Buchanan-Smith, J., & Campbell, C. (1998). Effects of forage vs grain feeding on carcass characteristics, fatty acid composition, and beef quality in Limousin-cross steers when time on feed is controlled. *Journal of Animal Science, 76*(10), 2619-2630.

Maughan, C., Tansawat, R., Cornforth, D., Ward, R., & Martini, S. (2012). Development of a beef flavor lexicon and its application to compare the flavor profile and consumer acceptance of rib steaks from grass- or grain-fed cattle. *Meat Science, 90*(1), 116-121.

McCluskey, J. J., Wahl, T. I., Li, Q., & Wandschneider, P. R. (2005). US grass-fed beef: marketing health benefits. *Journal of Food Distribution Research, 36*(3), 1-8.

Muir, P., Smith, N., Wallace, G., Cruickshank, G., & Smith, D. (1998). The effect of short-term grain feeding on liveweight gain and beef quality. *New Zealand Journal of Agricultural Research, 41*(4), 517-526.

Nollet, L. M., & Toldrá, F. (2010). *Handbook of Processed Meats and Poultry Analysis*: CRC Press, chapter 22 page 447.

Nuernberg, K., Dannenberger, D., Nuernberg, G., Ender, K., Voigt, J., Scollan, N. D., Wood, J., Nute, G., & Richardson, R. I. (2005). Effect of a grass-based and a concentrate feeding system on meat quality characteristics and fatty acid composition of longissimus muscle in different cattle breeds. *Livestock Production Science, 94*(1), 137-147.

Page, J., Wulf, D., & Schwotzer, T. (2001). A survey of beef muscle color and pH. *Journal of Animal Science, 79*(3), 678-687.

Pavan, E., & Duckett, S. K. (2013). Fatty acid composition and interrelationships among eight retail cuts of grass-fed beef. *Meat Science, 93*(3), 371-377.

Priolo, A., Micol, D., & Agabriel, J. (2001). Effects of grass feeding systems on ruminant meat colour and flavour. A review. *Animal Research, 50*(3), 185-200.

Razminowicz, R. H., Kreuzer, M., & Scheeder, M. R. L. (2006). Quality of retail beef from two grass-based production systems in comparison with conventional beef. *Meat Science, 73*(2), 351-361.

Realini, C. E., Duckett, S. K., Brito, G. W., Dalla Rizza, M., & De Mattos, D. (2004). Effect of pasture vs. concentrate feeding with or without antioxidants on carcass characteristics, fatty acid composition, and quality of Uruguayan beef. *Meat Science, 66*(3), 567-577.

Resconi, V. C., Escudero, A., Beltrán, J. A., Olleta, J. L., Sañudo, C., & Mar Campo, M. d. (2012). Color, lipid oxidation, sensory quality, and aroma compounds of beef steaks displayed under different levels of oxygen in a modified atmosphere package. *Journal of Food Science, 71*(1),S10-S18.

Sapp, P., Williams, S., & McCann, M. (1999). Sensory attributes and retail display characteristics of pasture-and/or grain-fed beef aged 7, 14 or 21 days. *Journal of Food Quality, 22*(3), 257-274.

Sawyer, J., Apple, J., & Johnson, Z. (2008). The impact of lactic acid concentration and sodium chloride on pH, water-holding capacity, and cooked color of injection-enhanced dark-cutting beef. *Meat Science, 79*(2), 317-325.

Scaglia, G., Fontenot, J., Swecker, W., Corl, B., Duckett, S., Boland, H., Smith, R., & Abaye, A. (2012). Performance, carcass, and meat characteristics of beef steers finished on 2 different forages or on a high-concentrate diet. *The Professional Animal Scientist, 28*(2), 194-203.

Scollan, N. D., Richardson, I., De Smet, S., Moloney, A. P., Doreau, M., Bauchart, D., & Nuernberg, K. (2005). Enhancing the content of beneficial fatty acids in beef and consequences for meat quality. *Indicators of milk and beef quality, EAAP Publications*(112), 151-162.

Sitz, B., Calkins, C. R., Feuz, D. M., Umberger, W. J., & Eskridge, K. M. (2005). Consumer sensory acceptance and value of domestic, Canadian, and Australian grass-fed beef steaks. *Journal of Animal Science, 83*(12), 2863-2868.

Stelzleni, A. M., & Johnson, D. D. (2008). Effect of days on concentrate feed on sensory off-flavor score, off-flavor descriptor and fatty acid profiles for selected muscles from cull beef cows. *Meat Science, 79*(2), 382-393.

Suman, S., Mancini, R., Joseph, P., Ramanathan, R., Konda, M., Dady, G., & Yin, S. (2010). Packaging-specific influence of chitosan on color stability and lipid oxidation in refrigerated ground beef. *Meat Science, 86*(4), 994-998.

Umberger, W. J. (2003). Country-of-origin labeling of beef products: US consumers' perceptions. University of Nebraska. *Journal of Food Distribution Research, 34*(3)*,* 103-116.

USDA. (1997). Official United States standards for grades of carcass beef. *Agricultural Marketing Service, Washington, DC*. *http://www.ams.usda.gov/AMSv1.0/getfile?dDocName=STELDEV3002979*

USDA-ERS. (2013). Livestock, Dairy and Poultry outlook. (September 18). *http://usda01.library.cornell.edu/usda/ers/LDP-M//2010s/2013/LDP-M-09-18-2013.pdf.*

Vestergaard, M., Oksbjerg, N., & Henckel, P. (2000). Influence of feeding intensity, grazing and finishing feeding on muscle fibre characteristics and meat colour of *semitendinosus*, *longissimus dorsi* and *supraspinatus* muscles of young bulls. *Meat Science, 54*(2), 177-185.

Williamson, C., Foster, R., Stanner, S., & Buttriss, J. (2005). Red meat in the diet. *Nutrition Bulletin, 30*(4), 323-355.

Wood, J., Richardson, R., Nute, G., Fisher, A., Campo, M., Kasapidou, E., Sheard, P., & Enser, M. (2004). Effects of fatty acids on meat quality: a review. *Meat Science, 66*(1), 21-32.

Wyrwisz, J., Półtorak, A., Zalewska, M., Zaremba, R., & Wierzbicka, A. (2012). Analysis of relationship between basic composition, pH, and physical properties of selected bovine muscles. *Bulletin of the Veterinary Institute in Pulawy, 56*(3), 403-409.

Yang, A., Lanari, M. C., Brewster, M., & Tume, R. K. (2002). Lipid stability and meat colour of beef from pasture- and grain-fed cattle with or without vitamin E supplement. *Meat Science, 60*(1), 41-50.

CHAPTER III

THE EFFECT OF FEEDING NATIVE WARM SEASON GRASSES IN THE STOCKER PHASE ON THE CARCASS QUALITY, MEAT QUALITY, AND SENSORY ATTRIBUTES OF BEEF LOIN STEAKS FROM GRAIN-FINISHED CATTLE

3.1 Introduction

Meat quality is influenced by extrinsic and intrinsic factors of which the animal's diet plays an important role (Priolo, et al., 2001, and Stelzleni & Johnson, 2008). Since the 1940s, cattle have been finished on grain to mature for market in a short period of time, which is known as feedlot feeding (Martin & Rogers, 2004). Beef quality from forage and grain-finished cattle has been researched extensively in the past (Bidner, 1981; Duckett, et al., 2009, Dunne, et al., 2005, Insani, et al., 2008; Kerth, et al., 2007, Maughan, et al., 2012, Moloney, et al., 2011, Mumford, 1911, Pavan & Duckett, 2013, Pordomingo, et al., 2012, Priolo, et al., 2001, Resconi, et al., 2012, Schaake, et al., 1993, Schmidt, et al., 2010, and Yang, et al., 2002). Conventionally, cattle are fed on grass in the stocker phase and finished on grain. Almost 85% of the beef raised and sold through retail outlets in the United States are finished on grain (Feuz, et al., 2004). However, increased grain prices and declining cattle prices have triggered the need for alternate feeding practices which can be utilized by farmers to reduce feeding costs (Peel, 2011). Consumer interest for forage-finished beef is increasing in the United States, which

provides additional market opportunities for exploring methods to utilize different forages in the stocker phase for both grain and forage-finished beef (Cox, et al., 2006, Martin & Rogers, 2004 and Mathews & Johnson, 2010).

Appearance is the primary factor that consumers use to make purchasing decisions when buying steaks in grocery stores (Dikeman, et al., 2005, Umberger, et al., 2009, and Bernues, et al., 2003). However, repeat purchases by consumers are predominantly determined by tenderness, flavor and juiciness (Dikeman, et al., 2005). Grain-finished cattle produce beef that is more tender, lighter in color and has less off-flavors than forage-finished beef (Priolo, et al., 2001, and Stelzleni & Johnson, 2008). Nevertheless, feeding cattle on high quality forages can also yield good quality tender beef (French, et al., 2001 and Latimori, et al., 2008). Although forage finish feeding of beef cattle has certain limitations such as increased production time, cost of production, seasonality of forage resources, economic risk and limited marketing potential, it offers certain advantages which includes low inputs, reduced use of antibiotics, leaner meat and perceived health benefits (Brewer & Calkins, 2003). Cattle finished on grain attain maturity for market in a shorter period of time and have better marbling scores than forage finished beef (Priolo, et al., 2001, and Stelzleni & Johnson, 2008). Also, grain-finished beef receives higher scores from consumers with respect to flavor, juiciness, tenderness and overall acceptability when compared to forage-finished beef (Sitz, et al., 2005). Rancid and grassy off-flavors are often associated with forage-finished beef which negatively impacts the eating quality of the meat. Forage-finished beef is darker and less red which is evidenced by lower L* and a* values, and yellow fat (higher b* values) (Realini, et al., 2004). Most recent reports on grain-finished cattle document better meat

quality (color, flavor, tenderness) when compared to forage-finished cattle (Pordomingo, et al., 2012, and Stelzleni & Johnson, 2008).

Bermudagrass is the most common grass that is used to graze cattle in the southern United States due to its large biomass production. Native Warm Season Grasses (NWSG) are inherent to the southeastern United States supports wildlife habitats and is used for grazing purposes. These forages are grazed by cattle, but there has been minimal research conducted on the quality of beef from cattle that were fed NWSG. Native Warm Season Grasses such as Indiangrass and Bluestem which are indigenous to southeastern United States provide superior wildlife habitats in comparison to non-native forages such as bermudagrass (Harper, 2007). In this research we evaluated the meat quality of beef cattle fed NWSG (Indiangrass monoculture and mixed forages of Indiangrass, Big Bluestem and Little Bluestem) during the stocker phase and finished on grain, and compared it with cattle that were fed bermudagrass during the stocker phase and finished on grain.

The specific objectives of the current study were to determine the carcass characteristics, chemical composition, meat quality and sensory attributes of beef from cattle that were fed either bermudagrass or NWSG during the stocker phase and then finished on grain. Beef quality was determined by evaluating loin steaks from each treatment for color, pH, instrumental tenderness, lipid oxidation, cooking loss, consumer and descriptive sensory characteristics and carcass characteristics. Differences in chemical composition between loin steaks were evaluated through proximate composition and fatty acid profile analyses.

3.2 Materials and Methods

3.2.1 Sample Collection

Animals (n=225) were grazed on three summer forage treatments (CON, Bermudagrass; IND, Indian monoculture; MIX, Mix of native warm season grasses (Mix sward of Indiangrass, Big bluestem and little bluestem)). This project was conducted at the MAFES (Mississippi Agriculture and Forestry Experiment Station) Prairie Research Unit starting May 2011. Cattle were allotted to three different forage treatments which were replicated three times. Eight animals were allotted to each replicate pasture plot within a treatment. Cattle (6 to 7 months old) grazed on these forages for 110 days, and seventy two steers were sent to a commercial feedlot (Iowa) and finished using a standard grain-based diet at the feedlot and harvested in March 2012. A three inch thick section was removed from the wholesale rib cut (*Longisimus lumborum*) at the 12th rib of each carcass after slaughter and fabricated into one inch steaks. The steaks were vacuum packaged separately and were shipped under refrigeration to the Department of Food Science, Nutrition and Health Promotion at Mississippi State University.

3.2.2 Meat Quality Analyses

Steaks were subjected to simulated retail display by placing them on styrofoam trays with soaker pads (Cryovac processor 3S trays yellow, Sealed Air, SC, USA) and overwrapping with an oxygen permeable PVC film (O2 permeability 780 cc/100 in 2/day; water permeability 14 g/100 in 2/ day; PVC Stretch Film, LINPAC Packaging – Filmco, Inc., U.S.A.). Steaks were stored under lights (Cool White 34 Watt, Sylvania Supersaver Ecologic, Danvers, MA) under refrigerated conditions (2 ºC at 800 lux) for 0, 3, 6 and 9 days. Six steaks from each treatment (two per replication) were randomly

selected and analyzed for color, pH, and lipid oxidation on the respective storage days. Separate steaks were used to determine proximate composition. Steaks that were displayed under lights for 0 and 9 days of storage were utilized for cooking loss and instrumental tenderness measurements. Eight steaks from each treatment were collected on day 0 and frozen at -20°C for sensory analyses that were conducted within 3 months of slaughter. In addition, steaks that were displayed for 0 days of storage were also utilized to determine fatty acid profiles.

3.2.3 Proximate Composition

Steaks (six per treatment, n=18) that were stored under light for 0 days were selected to determine moisture, fat, and protein content using a Near Infrared Spectrometer (NIR) (FoodScan Lab Analyzer Model 78810, FOSS Analytical A/S, Slangerupgade, DK, AOAC, 2007). Two steaks were obtained from each treatment for each replication prior to storage and separately analyzed for proximate composition. Fresh meat was ground with a meat grinder (Cabela's PRO 450, Cabela's, Sidney, NE) that was fitted with a 3-mm (1/8 inch) grinder plate. Ground samples were tightly packed into a 140-mm sample cup prior to analysis and were analyzed using the NIR.

3.2.4 Meat Color

At each refrigerated storage time (0, 3, 6, and 9 days), the color of beef steaks (n=6 per treatment) was measured using a chroma meter with a D-65 illuminant and an aperture size of 50 mm (Model CR-410, Minolta Camera Co., Ltd., Osaka, Japan Serial No C8202489) that was calibrated using a standard white calibration plate (Model No 20933026, Japan). Two steaks from each treatment, within each replication, were used to

measure instrumental meat color (expressed as CIE L*, a*, b*, hue, and chroma values). The color attributes were measured at four identical locations on each steak and averaged at 0, 3, 6, and 9 days of storage respectively. The bloom time was 60 min between fabrication and the packaging of steaks. The steak samples were removed from the packages on each day of storage (0, 3, 6, 9 days) and color attributes were measured on each steak using a hand held chroma meter. The values were recorded for each steak and averaged for final reporting.

3.2.5 Meat pH

The pH of two steaks from each treatment, within each replication was determined using an Accumet pH meter (Model Accumet 61, Fisher Scientific Hampton, NH, USA) with a meat penetrating pH probe (FlexipHet SS Penetration Tip, Cole Palmer, Vernon Hills, IL) that was calibrated with pH standards of 4.0 and 7.0 after 0, 3, 6, and 9 days of refrigerated storage. pH was measured on steak samples on each day of storage that color measurements were determined. A pH penetrating probe which was attached to a pH meter was used by inserting the pH probe into the steak samples and values were recorded. For each steak, two measurements were recorded and averaged for final reporting.

3.2.6 Thiobarbituric Acid Reactive Substances

Lipid oxidation of beef steaks was determined using a Thiobarbituric acid reactive substances (TBARS) assay and expressed as milligrams of malonaldehyde per kilogram of sample (Yin, 1993). Two steak samples were randomly selected for TBARS measurements from each replication for each of the 3 treatments at 0, 3, 6 and 9 days of

storage. The same steaks that were used for color and pH analysis were used to measure TBARS. Five g samples from each steak were weighed in duplicate from different portions of the steak, mixed with 11% trichloroacetic acid, homogenized in a blender (Osterizer Galaxie, Oster Corporation, Milwaukee, WI) and filtered using Whatman filter paper no. 1. Two ml of filtrate was then mixed with 2 ml of 20 mM thiobarbituric acid and incubated at 25 ºC for 20 h. Absorbance of the solution was recorded at 532 nm and the concentration of MDA mg/kg was calculated using a standard curve. At each storage time, six samples per treatment were analyzed with a total of eighteen samples that were analyzed in duplicate.

3.2.7 Aerobic Plate Count

Aerobic plate count was determined for beef steaks using a method described by Vanderzant & Splittstoesser (1992). The same steaks that were used for color, pH and lipid oxidation measurements were also used to determine aerobic plate count at each storage time. Microbial determination was conducted prior to any other analysis at each storage day (0, 3, 6, and 9 days) to avoid any contamination while determining other meat quality parameters such as pH, color and lipid oxidation. A 10 g sample was taken in duplicate from each selected steak under aseptic conditions and 90 ml of 0.1% sterilized peptone water was added to the sample in a stomacher bag. Sample bags were stomached for 45 s in a stomacher (Whirl-Pak, Nasco, Fort Atkinson, WI, USA) and subsequent serial dilutions were made in 0.1% peptone water. Up to four dilutions were prepared and plated for the aerobic plate counts. Dilutions which had countable colonies (between 1-300 colonies) were selected to calculate CFU per g of sample. The aerobic plate count was determined by spread plating 1 ml of homogenate on the APC petrifilm (3M

Petrifilm Aerobic Count Plates, 3M, MN, USA). Plates were incubated aerobically (37 °C) for 48 h prior to colony counting. APC was reported as $\log_{10}$ of colony forming units (CFU) per g.

3.2.8 Fatty Acid Profile

3.2.8.1 Sample Preparation

For fatty acid profile determination, three previously frozen steaks per treatment were thawed out for 24 h at 2 °C. Enough sample (approximately 300g) was taken so that thirty to fifty grams of fat was extracted out of the meat sample into a mojonnier flask. To each sample flask, 1 ml of chloroform containing Triundecanoin (10mg/ml), hydrochloric acid-water mixture (70:30), 2 ml ethanol and 100 mg of pyrogallolic acid were added and samples were placed in a shaking water bath at 75 °C for 40 min. Samples were extracted first using diethyl ether and then petroleum ether; both ether extracts were collected into a 250 ml beaker with boiling beads, and then gently boiled in a steam bath to dryness. Four ml of 0.5N NaOH in methanol and 10 ml of hexane were added to the beaker prior to transfer to a 125 ml flat-bottom flask with a ground glass joint that was attached to a condenser. The solution was boiled and refluxed gently until the fat was dissolved. Five ml of borontrichloride in methanol was added and boiled for 2 min. This liquid was transferred to a 125 ml separatory funnel, and 15 ml of saturated aqueous NaCl solution was added. The mixture was shaken, and the bottom layer was discarded. The top layer was retained and was dried by passing the isooctane layer through granular sodium sulphate. The filtrate was collected, and the volume was adjusted to 10 ml. Prior to GC analysis, a 1:10 dilution was made with hexane.

3.2.8.2 Gas Chromatography Analysis

Fatty Acid Methyl Esters (FAME) were analyzed using a modified method (AOAC 996.06, 17th edition, AOAC, 2000, 2000a, 2000b) for a GC/ FID (Varian 3400 gas chromatograph with a flame ionization detector, a Model 8200 Varian autosampler, CA, USA), and a sol gel wax column (30 meter x 0.25 mm ID x 0.25 mm phase thickness). The program was initiated at 50 °C for 3 min and subsequently ramped to 220°C at 4 °C/min increments. The injector and detector were maintained at 200 °C and 300 °C, respectively. The injection volume was 1 µl and the column gas flow was 1 ml/min. Hydrogen was used as the carrier gas at a flow rate of 30 ml/min. The fatty acids were identified by comparing retention times with standards.

3.2.9 Cooking Loss

Two frozen steak samples from each replication were used from each treatment. Samples were thawed at 2°C overnight prior to cooking. After determining raw weights, steaks were roasted at 177°C in an oven (JBP25DOJ2WH, General Electric, Louisville, KY) to a final internal temperature of 71°C. Internal steak temperatures were assessed using meat thermocouples (thermocouple type-T connected with UWTC-1 connectors and wireless RF receiver UWTC, Omega Engineering, Inc., Stamford, CT, U.S.A.) by inserting the thermocouples into the thickest portion of each steak sample. Cooked steak samples were removed and allowed to rest for an hour to equilibrate to a room temperature. Residual moisture was removed from each sample with a paper towel by blotting for 10 s prior to reweighing. Cooking loss was reported as a percentage and calculated as follows:

$$\% \text{ cook loss} = [(\text{raw weight} - \text{cooked weight})/ \text{raw weight}] \times 100 \quad (3.1)$$

3.2.10 Instrumental Tenderness

Instrumental tenderness was determined for six steaks per treatment (two steaks per replication) using a procedure described by Schmidt et al., (2010). Frozen steaks for each treatment were thawed at 4°C for 20 h. Each steak was cooked as described in the cooking loss section. Steaks were then allowed to cool to approximately 20 °C (ambient temperature) and 6-8 cores (12.7 mm diameter) were removed parallel to the muscle fibers for each steak. Cores were sheared perpendicular to the muscle fibers using a Warner–Bratzler shear attachment that was mounted to an Instron Universal Testing Center (Model 3300, Instron, Norwood, MA, USA) using a 500 N load transducer and a cross-head speed of 200 mm/min. The average for maximum peak force was calculated for each steak and treatment means were reported as Warner Bratzler shear force (N).

3.2.11 Consumer Acceptability

Three consumer based sensory panels (n=180) were conducted to evaluate the acceptability of beef steaks. The participants consisted of students, staff and faculty at Mississippi State University. Samples (two per rep and six per treatment) were cooked as described for cooking loss and tenderness determinations. Steak samples were cooked to an internal temperature of 71 °C, cooled for 15 min, cut into 2.54 cm cubes and stored in a covered chafing dish (60 °C) until panelists evaluated the samples (AMSA, 2012). Labeled plastic cups with lids (Sweetheart Cup Co., Owning Mills, MD) with random three-digit numbers were used to identify each sample, and each participant evaluated three treatment samples in a booth under red light. Participants were asked to evaluate

overall acceptability and acceptability in respect to appearance, texture and flavor on a nine point hedonic scale in individual booths (Meilgaard, et al., 2007). The scale was categorized as: nine=like extremely, eight=like very much, seven=like moderately, six=like slightly, five=neither like nor dislike, four=dislike slightly, three=dislike moderately, two=dislike very much, one-dislike extremely. Acceptability of texture was defined as product liking in respect to tenderness. Acceptability of appearance was defined as product liking in respect to color and visible moisture, and acceptability of flavor was defined as product liking in respect to beef flavor (taste). Panelists were asked to evaluate all attributes for each sample before evaluating the next sample, and to evaluate one sample at a time going from left to right on the score sheet. Sample order was also randomized to account for sampling order bias. Panelists evaluated beef samples that were coded with random 3 digit number and recorded their responses using compusense software (compusense five, Compusense Inc. Guelph, Ontario, Canada). Water, apple juice and unsalted crackers were provided, and panelists were asked to expectorate and rinse their mouths with apple juice between each sample.

3.2.12 Descriptive Analysis

For descriptive analysis of the steak samples, eight panelists with an average of 50 hrs of previous experience evaluating meat products were trained for 5 to 10 h according to American Meat Science Association guidelines (AMSA, 2012, Meilgaard, et al., 2007, and Schilling & Pham, 2012). Three samples were cooked at each time from each treatment with three replications and three samples from each treatment were presented to panelists. The following scale was used for evaluating myofibrillar and overall tenderness, 1 = extremely tough and 8 = extremely tender (AMSA, 2012). For the amount

of connective tissue that was present in the sample, the following scale was used: 1 = abundant and 8 = none. For initial and sustained juiciness, an eight-point hedonic scale was used where 1 = extremely dry and 8 = extremely juicy. Additional training sessions were performed to train panelists with respect to beef aroma, beef flavor, flavor intensity, bloody (flavor associated with under-cooked meat), metallic, brown/burnt, liver, and roasted on a fifteen point scale line (0 = none for the descriptor and 15 = maximum intensity) (Maughan, et al., 2012). Samples were cooked as described in the cooking loss section, cut into 2.54 cm cubes and evaluated by an eight-member trained sensory panel (AMSA, 1995). Steak pieces were served in 2 oz. plastic containers (Sweetheart Cup Co., Owing Mills, MD) that were coded with random three-digit numbers. Four sessions were conducted for descriptive sensory analysis of beef steaks, one session on each day of display time period. The order of presentation of the samples was randomized to prevent bias. Panelists were provided with water, apple juice and expectorant cups to cleanse their palate between sample evaluations.

3.2.13 Statistical Analyses

A completely randomized design with 3 replications (n =3 with 8 cattle per treatment within each replication) was utilized to test the effects of diet on the proximate composition, tenderness, and fatty acid profile of *longissimus* steaks (Statistical Analysis Software, version 9.1, SAS Institute, Cary, NC). In addition, a factorial structure within the completely randomized design was utilized to evaluate pH, color, lipid oxidation, and sensory characteristics since steak samples were analyzed over storage time from each dietary treatment. When differences existed among treatments ($P<0.05$), the Fisher's Protected Least Significant Difference (LSD) test was used to separate treatment means.

For the preference and liking of the beef steaks, agglomerative hierarchical clustering using Wards Method (XL Stat 2006) was performed to group panelists together based on preference and liking of steak samples. The panelists were grouped into clusters based on a dissimilarity plot and a dendrogram. After separating the data into clusters, the entire data set was evaluated to confirm that the data for each panelist was relatively close to the means of the treatments that were within the cluster that they were grouped into. After conducting agglomerative hierarchical clustering, randomized complete block designs (panelists as blocks), were used within each cluster, and Fisher's protected LSD test was utilized to separate treatment means within a cluster when differences occurred ($P<0.05$).

3.3 Results and Discussions

3.3.1 Carcass Quality

Table 3.1 shows the carcass quality of cattle that were fed different grasses in the stocker phase and finished on grain. Approximately 94% of carcasses graded 'choice'. The percentage of choice carcasses from each treatment was 100%, 95.8% and 87% for MIX, CON, and IND, respectively. Treatments IND and CON yielded 13% and 4.2% 'select' carcasses. No differences existed ($P>0.05$) between treatments with respect to quality and yield grade. Kerth et al. (2007) reported that the carcass quality from cattle fed with rye grass and finished on grain was similar to the results in this study.

3.3.2 Proximate Composition

Steaks from the CON treatment had greater ($P<0.05$) fat content and less ($P<0.05$) protein and moisture content than steaks from IND and MIX treatments (Table 3.1). There was no difference ($P>0.05$) in collagen content between the treatments. Moisture

content in our study was similar (68%) to the results reported by Baublits et al. (2006) with 69% moisture in choice steaks. Fat percentage was also similar to the 7% fat content yielded for choice steaks (Baublits, et al., 2006). In contrast, Duckett et al. (2009) reported 74% moisture and 4.1% fat for *longissimus* muscle from concentrate finished beef. Similar results were reported by Leheska et al. (2008) in which moisture and fat percentage were 71% and 4%, respectively.

3.3.3 Meat Color

There were no differences ($P>0.05$) in L* (lightness) among treatments or between storage times (Table 3.2). There was no difference ($P>0.05$) in CIE a* (redness) values between treatments at each storage time, but redness decreased ($P<0.05$) as storage time increased, which is due to the conversion of oxymyoglobin to metmyoglobin. No differences existed in b* (yellowness) among treatments at each storage time, but the b* value decreased over storage time with the exception of day 6 and day 9 for the control treatment. Also, the hue and chroma values were not different ($P>0.05$) among treatments, but differed over storage time. Chroma values decreased ($P<0.05$) whereas hue values increased ($P<0.05$) for each treatment over storage time which is correlated to a decrease in a* value. Similar to the present study, Daniel et al. (2009) reported that redness and yellowness of beef steaks decreased during retail display.

3.3.4 Meat pH

Meat pH decreased from day 3 of storage to day 9 of storage for the CON and IND treatments and from day 6 to day 9 for the MIX treatment (Table 3.3). This may be

due to the increase in bacterial counts, specifically lactic acid bacteria, which produce acid during metabolism and lower the pH of meat.

3.3.5 Thiobarbituric Acid Reactive Substances

Lipid oxidation increased from day 3 to day 6 for CON steaks and from day 6 to day 9 for the IND and MIX treatments (Table 3.3). The increase in lipid oxidation for CON steaks can be attributed to the higher amount of fat in CON (7.7% fat), which makes CON steaks more susceptible to lipid oxidation. In addition, TBARS values were lower at day 6 for the IND and MIX treatments when compared to the CON treatment. This indicates that the rate of lipid oxidation increased more rapidly in the CON treatment when compared to the IND and MIX treatments.

3.3.6 Aerobic Plate Count

There were no differences ($P>0.05$) in microbial counts between treatments at each storage time with the exception of the MIX treatment having higher counts than steaks from the CON treatment on day 9 (Table 3.3). The microbial counts on day 0 of storage were 4 logs and then increased to approximately 5 logs at day 9. Because of different harvesting sites for our grain-finished study and forage-finished studies (chapter IV), there was a difference of 2 logcfu/g between the studies for steaks that were evaluated on day 0 of retail display. This would indicate that the end of shelf-life for the beef steak was due to color discoloration from myoglobin oxidation and not microbial growth. Researchers have reported that a microbial load of 7 logs in beef steaks is spoiled and that off odors have developed that lowers the organoleptic quality of the meat (Ercolini, et al., 2011 and Ercolini, et al., 2006).

3.3.7 Cooking Loss

No difference existed (P>0.05) in cooking loss for beef steaks from the different treatments (Table 3.3). There was no treatment by day interaction (P>0.05) among the steaks from cattle that were fed different grasses in the stocker phase. Schmidt et al. (2010) reported similar cooking loss values (27 %) for choice steaks with a similar cooking method when cattle were finished on concentrate. Dawson, (2012) also reported cooking loss values of 28 % for *longissimus* steaks from cattle that were fed varying diets of grass silage in the stocker phase and then finished on concentrate.

3.3.8 Instrumental Tenderness

The force (N) that is required to shear through steaks did not differ (P>0.05) between treatments (Table 3.3). The average shear force value for beef steaks was 27 N which is considered tender (Lage, et al., 2012, Razminowicz, et al., 2006, and Schmidt, et al., 2010) for *longissimus* steaks that were cooked at a temperature of 71°C. Generally, conventional or grain finished beef are more tender than beef from forage finished cattle (Kerth, et al., 2007). However, researchers have also reported no difference in tenderness between beef from grain finished and forage finished cattle (Duckett, et al., 2007, Realini, et al., 2004).

3.3.9 Fatty Acid Profile

No differences existed in percentage fatty acid content with the exception of linoleic acid (C18:2) which was greater in steaks from IND when compared to steaks from CON and MIX treatments (Table 3.4). Since minimal differences existed among treatments, the greater fat percentage in steaks from the CON treatment likely led to a

more rapid increase in oxidation (TBARS) in the steaks from the CON treatment when compared to the other steaks (Table 3.3, Table 3.4). The percentages of fatty acids reported in the literature were in agreement with our findings. Leheska et al. (2008), Descalazo et al. (2005), and Realini et al. (2004) reported fatty acid composition in *longissimus* muscle of beef cattle that are similar to our results.

3.3.10 Consumer Acceptability

On average, no differences ($P>0.05$) existed among treatments with respect to appearance, aroma, flavor, texture and overall acceptability (Table 3.5). The average scores given by consumers for beef steaks on a nine point hedonic scale was between like slightly and like moderately. Maughan et al. (2012) reported acceptability scores between 6.08 (like slightly) and 7.05 (like moderately), which are similar to the results from the current study. No differences ($P>0.05$) existed among the treatments with respect to appearance, aroma, flavor, texture and overall acceptability of beef steaks. Consumers were grouped into clusters based on preference and liking of steaks (Table 3.6). Cluster 1 (23 % of panelists) rated beef steaks between like very much and like moderately, and no differences existed ($P>0.05$) among treatments for this group of consumers. Cluster 2 (17 % of panelists) preferred ($P<0.05$) steaks from the IND and CON treatments over steaks from the MIX treatment. Consumers in this group rated CON and IND treatments like moderately and rated MIX treatment neither like nor dislike. Cluster 3 (27 % of panelists) preferred ($P<0.05$) steaks from MIX and IND treatment over CON treatment. The rating was between like moderately and like very much for steaks from IND and MIX treatments and like moderately for CON treatment. Cluster 4 (18 % of panelists) preferred ($P<0.05$) steaks from the MIX treatment over steaks from the IND and CON

treatments. They rated MIX treatment between like slightly and like moderately and rated CON and IND treatments approximately neither like nor dislike. Cluster 5 (14 % of panelists) preferred ($P<0.05$) MIX and CON treatments over IND treatment. These panelists rated IND treatment neither like nor dislike and rated CON and MIX treatments like moderately. Grouping of consumers by cluster analysis indicated that 59.8% of consumers preferred MIX steaks over steaks from the CON treatment, while 17 % of panelists preferred ($P<0.05$) the CON steaks over the steaks from MIX treatment. Forty-five % of panelists preferred steaks from IND treatment over steaks from CON treatment and 14.4 % preferred steaks from CON treatment over steaks from IND treatment. In addition, 32.5 % of panelists preferred steaks from MIX treatment over steaks from IND and 17 % preferred IND steaks over MIX steaks.

3.3.11 Descriptive Sensory Analysis

No differences ($P>0.05$) existed between the treatments at each storage time. However, beef aroma, beef flavor, umami taste, and initial juiciness decreased ($P<0.05$) over storage time. The scores given by the panelists for these attributes were lowest on day 9 when compared to day 0 (Tables 3.7 and 3.8). This decrease in beef flavor can be particularly attributed to the formation of secondary oxidation compounds from the fatty acids which imparted rancidity and off-flavor and decreased beef flavor intensity. Baublits, et al., (2006) and Kerth, et al., (2007) reported that grain finished cattle were higher in beef flavor intensity and tenderness than cattle that were finished on ryegrass. Results indicate that even though the sensory quality decreased over storage time, the end of shelf life was due to myoglobin oxidation to metmyoglobin as evidenced by color data.

3.4 Conclusions

The overall quality of beef steaks from cattle that were fed different diets in the stocker phase was similar. Composition and eating quality of beef steaks from cattle that were fed bermudagrass was similar to that of steaks from cattle that were fed native warm season grasses during the stocker phase. This indicates that native warm season grasses can be incorporated in the stocker phase of cattle when finished on grain and not affect the quality of beef from these production systems. These grasses are native to the southeastern United States and can be used as forage and also support the habitats of many wildlife. In addition, feeding mixed native warm season grasses yielded meat that was less susceptible to lipid oxidation and lower in total fat percentage with similar quality grades to cattle fed bermudagrass. This further indicates that native warm season grass could be acceptable forage since it is resistant to drought and leads to greater daily weight gain in cattle when compared to bermudagrass.

3.5 Tables

Table 3.1 Carcass quality and proximate composition (%) of beef ribeye steaks from cattle that were fed bermudagrass and native warm season grass

Attribute	CON (%)	IND (%)	MIX (%)	SEM
Quality Grade				
Choice +		4.4	4.2	
Choice	37.5	8.7	25.0	
Choice -	58.3	73.9	70.8	
Total choice	95.8	87.0	100	2.8
Select +	4.2	8.7		
Select -		4.4		
Total Select	4.2	13.1		2.8
Yield Grade	3.6[a]	3.6[a]	3.7[a]	0.1
Proximate Composition				
Protein (%)	22.2[b]	22.8[a]	23.0[a]	0.06
Fat (%)	7.7[a]	5.8[b]	6.6[b]	0.1
Moisture (%)	68.0[b]	69.5[a]	69.0[a]	0.1
Collagen (%)	1.2[a]	1.3[a]	1.4[a]	0.1

[a-c] Means within a row with the same letter are not different (P>0.05)
SEM Standard error of means
CON: Control (Bermudagrass), IND: Indiangrass, MIX: Mix of Native Warm Season Grasses

Table 3.2 Instrumental color (CIE L* a* b*, hue, and chroma) of beef ribeye steaks from cattle that were fed bermudagrass and native warm season grass that were stored in a refrigerated retail display for 0, 3, 6, and 9 days

Attribute	Treatment	Day 0	Day 3	Day 6	Day 9	SEM
L* value	CON	46.4^{aX}	45.7^{aX}	44.4^{aX}	44.6^{aX}	
	IND	44.3^{aX}	44.3^{aX}	45.0^{aX}	43.8^{aX}	
	MIX	44.9^{aX}	45.1^{aX}	45.4^{aX}	44.9^{aX}	0.4
b* value	CON	11.6^{aX}	10.6^{bX}	8.2^{cy}	8.0^{cX}	
	IND	11.6^{aX}	10.2^{bX}	8.8^{cXY}	7.2^{dX}	
	MIX	12.0^{aX}	10.6^{bX}	9.2^{cX}	7.9^{dX}	0.1
a* value	CON	26.2^{aX}	24.2^{aX}	17.6^{bX}	14.1^{bX}	
	IND	27.1^{aX}	24.4^{aX}	19.8^{bX}	14.0^{cX}	
	MIX	27.5^{aX}	24.4^{abX}	21.1^{bX}	16.4^{cX}	0.1
Chroma	CON	28.7^{aX}	26.4^{aX}	19.4^{bY}	16.3^{cX}	
	IND	29.5^{aX}	26.3^{bX}	21.7^{cXY}	15.8^{dX}	
	MIX	30.0^{aX}	26.6^{bX}	23.0^{cX}	18.2^{dX}	0.5
Hue	CON	23.8^{aX}	23.6^{aX}	25.4^{aX}	31.3^{bX}	
	IND	23.2^{aX}	22.7^{aX}	24.2^{abX}	27.7^{bXY}	
	MIX	23.7^{aX}	23.5^{aX}	23.6^{aX}	25.7^{aY}	0.7

$^{a-d}$ Means within a row with the same letter are not different (P>0.05)
$^{X-Z}$ Means within a column within an attribute with the same letter are not different (P>0.05)
SEM Standard error of means
CON: Control (Bermudagrass), IND: Indiangrass, MIX: Mix of Native Warm Season Grasses

Table 3.3 Quality of beef ribeye steaks that were subjected to simulated retail display stored for 0, 3, 6, and 9 days with treatments that include feeding of bermudagrass and native warm season grass

Attribute	Treatment	Day 0	Day 3	Day 6	Day 9	SEM
pH	CON	5.74^{aY}	5.77^{aXY}	5.62^{bz}	5.57^{cX}	
	IND	5.78^{aX}	5.80^{aX}	5.68^{bY}	5.57^{cX}	
	MIX	5.77^{aXY}	5.70^{bZ}	5.73^{bX}	5.58^{cX}	0.01
Lipid oxidation (mg MDA/kg)	CON	0.19^{bX}	0.43^{bX}	0.80^{aY}	0.90^{aY}	
	IND	0.12^{cX}	0.20^{bX}	0.40^{bY}	0.90^{aX}	
	MIX	0.10^{bX}	0.19^{bX}	0.30^{bY}	0.70^{aX}	0.04
Aerobic Plate Count (log CFU/g)	CON	4.3^{bX}	5.0^{aX}	4.7^{abX}	4.9^{bX}	
	IND	4.3^{bX}	4.9^{aX}	4.5^{bX}	5.3^{aXY}	
	MIX	4.1^{cX}	4.8^{bX}	4.5^{bcX}	5.6^{aY}	0.1
Cooking loss (%)	CON	26.6^{aX}	N/A	N/A	26.4^{aX}	
	IND	25.6^{aX}	N/A	N/A	25.8^{aX}	
	MIX	27.0^{aX}	N/A	N/A	24.7^{aX}	0.8
W.B. Shear force (N)	CON	26.5^{aX}	N/A	N/A	26.4^{aX}	
	IND	29.9^{aX}	N/A	N/A	27.9^{aX}	
	MIX	30.4^{aX}	N/A	N/A	27.3^{aX}	1.5

$^{a-c}$ Means within a row with the same letter are not different (P>0.05)
$^{X-Z}$ Means within a column within an attribute with the same letter are not different (P>0.05)
SEM Standard error of means
CON: Control (Bermudagrass), IND: Indiangrass, MIX: Mix of Native Warm Season Grasses

Table 3.4 Fatty acid profile (triglyceride equivalent %) of beef ribeye steaks from cattle that were fed bermudagrass and native warm season grass

Triglyceride Equivalent %	**CON**	**IND**	**MIX**	**SEM**
C14:0 Myristic TE(%)	3.3[a]	3.0[a]	3.4[a]	0.1
C15:0 Pentadecanoic TE(%)	0.5[a]	0.4[a]	0.6[a]	0.1
C16:0 Palmitic TE(%)	29.4[a]	27.7[a]	28.8[a]	0.5
C17:0 Heptadecanoic TE(%)	1.5[a]	1.3[a]	1.4[a]	0.1
C18:0 Stearic TE(%)	18.0[a]	17.1[a]	17.2[a]	0.5
C20:0 Arachidic TE(%)	0.1 [a]	0.2[a]	0.2[a]	0.02
C14:1 Myristoleic TE(%)	0.6[a]	0.7[a]	0.7[a]	0.1
C16:1 Palmitoleic TE(%)	3.0[a]	3.0[a]	3.3[a]	0.1
C18:1cis Oleic TE(%)	39.1[a]	40.5[a]	39.2[a]	0.8
C18:2 cis Linoleic TE(%)	4.3[b]	5.7[a]	4.8[b]	0.1
C18:3n9 Linolenic TE(%)	0.2[a]	0.2[a]	0.2[a]	0.02
C20:1 Eicosenoic TE(%)	0.2[a]	0.2[a]	0.2[a]	0.03

[a-c] Means within a row with the same letter are not different (P>0.05)
SEM Standard error of means
CON: Control (Bermudagrass), IND: Indiangrass, MIX: Mix of Native Warm Season Grasses

Table 3.5 Consumer acceptability (n=180) of ribeye steaks from cattle that were fed bermudagrass and native warm season grass

Attributes	CON	IND	MIX
Appearance	6.9	7.0	7.0
Aroma	6.5	6.7	6.7
Flavor	6.9	6.8	6.9
Texture	6.5	6.7	6.7
Overall acceptability	6.7	6.9	6.8

Nine point hedonic scale: 1 = Dislike extremely and 9 = Like extremely
CON: Control (Bermudagrass), IND: Indiangrass, MIX: Mix of Native Warm Season Grasses

Table 3.6 Acceptability of beef ribeye steaks from the cattle that were fed bermudagrass and native warm season grass according to different consumer groups

Clusters	Panelists (%)	CON	IND	MIX
1	23.2	8.2[a]	7.9[a]	7.8[a]
2	17.0	6.8[a]	7.1[a]	4.8[b]
3	27.3	6.7[b]	7.5[a]	7.7[a]
4	18.1	4.6[c]	5.3[b]	6.5[a]
5	14.4	7.0[a]	5.7[b]	7.0[a]

[a-c] Means within a row with the same letter are not different (P>0.05)
Nine point hedonic scale: 1 = Dislike extremely and 9 = Like extremely
CON: Control (Bermudagrass), IND: Indiangrass, MIX: Mix of Native Warm Season Grasses

Table 3.7 Descriptive sensory attributes and intensity scores (aroma and flavor) of beef steaks from cattle that were fed bermudagrass (CON) and native warm season grass (IND and MIX) and subjected to simulated retail display for 0, 3, 6, and 9 days

Days	0			3			6			9			
Treatments	CON	IND	MIX	CON	IND	MIX	CON	IND	MIX	CON	IND	MIX	SEM
Aroma													
Beef	5.4^{ab}	5.4^{ab}	5.5^{ab}	5.7^{ab}	5.8^{a}	5.7^{a}	6.0^{a}	5.7^{a}	5.2^{abc}	5.0^{bc}	4.5^{c}	4.5^{c}	0.2
Roasted/Browned	3.4^{a}	3.3^{a}	3.2^{a}	3.0^{abc}	3.1^{abc}	3.0^{abc}	2.9^{abc}	3.1^{ab}	2.8^{abc}	2.9^{abc}	2.2^{bc}	2.1^{bc}	0.1
Grassy	1.3^{a}	1.0^{a}	1.3^{a}	1.0^{a}	0.9^{a}	0.9^{a}	1.2^{a}	1.3^{a}	0.9^{a}	1.4^{a}	1.4^{a}	1.4^{a}	0.1
Livery	2.0^{a}	2.0^{a}	1.8^{a}	2.1^{a}	1.8^{a}	1.8^{a}	2.1^{a}	2.3^{a}	1.8^{a}	2.1^{a}	1.9^{a}	2.1^{a}	0.1
Rancid/Oxidized	0.4^{c}	0.2^{c}	0.2^{c}	0.2^{c}	0.3^{c}	0.3^{c}	1.0^{b}	0.9^{b}	0.6^{bc}	1.5^{a}	1.8^{a}	1.8^{a}	0.1
Flavor													
Beef	5.8^{b}	6.1^{ab}	6.5^{a}	6.0^{ab}	5.5^{b}	6.1^{a}	5.7^{b}	5.9^{ab}	5.3^{b}	4.1^{c}	4.3^{c}	4.4^{c}	0.2
Beef broth	3.3^{ab}	3.5^{a}	3.7^{a}	2.8^{abc}	3.0^{abc}	3.1^{ab}	2.7^{bc}	2.9^{abc}	2.7^{bc}	2.3^{c}	2.5^{c}	2.9^{bc}	0.1
Roasted/Browned	2.9^{ab}	3.1^{ab}	3.3^{a}	3.0^{ab}	2.8^{abc}	2.8^{abc}	2.5^{bc}	3.0^{abc}	2.5^{bc}	2.3^{c}	2.3^{c}	2.2^{c}	0.2
Serumy	3.7^{a}	4.0^{a}	3.8^{a}	2.9^{c}	3.1^{bc}	3.3^{abc}	3.4^{abc}	2.9^{bc}	3.3^{abc}	2.5^{c}	2.8^{c}	3.3^{abc}	0.2
Rancid	0.3^{c}	0.2^{c}	0.2^{c}	0.3^{c}	0.5^{c}	0.2^{c}	1.0^{bc}	0.8^{bc}	0.7^{c}	1.9^{a}	1.7^{ab}	2.0^{a}	0.1
Fatty	1.8^{ab}	1.7^{b}	2.2^{a}	1.6^{bc}	1.7^{bc}	1.7^{bc}	1.6^{bc}	1.8^{abc}	1.8^{abc}	1.4^{bc}	1.5^{bc}	1.6^{bc}	0.1
Livery	2.5^{abc}	3.0^{a}	2.8^{ab}	2.1^{bc}	2.0^{c}	2.0^{c}	2.5^{abc}	2.3^{abc}	2.3^{abc}	1.9^{c}	1.9^{c}	2.0^{c}	0.1
Grassy	1.1^{a}	1.4^{a}	1.5^{a}	1.7^{a}	1.2^{a}	1.1^{a}	1.1^{a}	1.3^{a}	1.1^{a}	1.2^{a}	1.2^{a}	1.4^{a}	0.1
Grainy	1.3^{ab}	1.4^{a}	1.2^{a}	1.3^{ab}	1.2^{a}	1.3^{ab}	1.4^{ab}	1.3^{ab}	1.3^{ab}	0.9^{c}	0.9^{c}	1.0^{c}	0.1
Nutty	1.2^{a}	1.2^{a}	1.0^{a}	1.3^{a}	1.0^{a}	1.3^{a}	1.4^{a}	1.4^{a}	1.3^{a}	1.5^{a}	1.4^{a}	1.4^{a}	0.1
Metallic	1.2^{a}	1.9^{a}	1.8^{a}	1.5^{a}	1.5^{a}	1.5^{a}	1.4^{a}	1.7^{a}	1.4^{a}	2.1^{a}	2.2^{a}	2.1^{a}	0.1
Astringent	1.1^{a}	1.2^{a}	1.2^{a}	1.1^{a}	1.1^{a}	1.0^{a}	1.2^{a}	1.2^{a}	1.0^{a}	1.5^{a}	1.4^{a}	1.8^{a}	0.1

$^{a-c}$ Means within a row with the same letter are not different (P>0.05)

CON: Control (Bermudagrass), IND: Indiangrass, MIX: Mix of Native Warm Season Grasses

Table 3.8 Descriptive sensory attributes and intensity scores (basic taste and texture) of beef steaks from cattle that were fed bermudagrass and native warm season grass and subjected to simulated retail display for 0, 3, 6, and 9 days

Days	0			3			6			9			
Treatments	CON	IND	MIX	CON	IND	MIX	CON	IND	MIX	CON	IND	MIX	SEM
Basic Taste													
Sweet	1.3^{a}	1.2^{b}	1.4^{b}	1.2^{abc}	1.1^{abc}	1.1^{abc}	1.1^{bc}	1.0^{bc}	1.0^{abc}	1.1^{abc}	1.0^{bc}	1.0^{c}	0.1
Salty	1.5^{a}	1.6^{a}	1.6^{a}	1.5^{a}	1.3^{bc}	1.7^{a}	1.5^{ab}	1.6^{a}	1.5^{ab}	1.1^{c}	1.2^{c}	1.2^{c}	0.1
Bitter	0.9^{a}	0.9^{a}	0.7^{a}	0.9^{a}	0.9^{a}	0.8^{a}	0.9^{a}	0.8^{a}	0.8^{a}	0.8^{a}	0.8^{a}	0.9^{a}	0.1
Sour	1.0^{bc}	0.9^{c}	0.7^{c}	0.8^{c}	0.8^{c}	0.8^{c}	1.1^{abc}	1.3^{abc}	1.0^{bc}	1.3^{ab}	1.4^{ab}	1.6^{a}	0.1
Umami	3.3^{a}	3.4^{a}	3.4^{a}	3.2^{a}	2.7^{abc}	3.1^{ab}	2.9^{abc}	3.1^{ab}	2.8^{abc}	2.2^{c}	2.2^{c}	2.5^{bc}	0.1
Texture													
Initial Juiciness	5.4^{ab}	5.7^{a}	5.8^{a}	5.4^{ab}	5.0^{bc}	5.5^{ab}	4.7^{c}	5.4^{ab}	5.3^{ab}	4.6^{c}	4.7^{c}	4.9^{c}	0.1
Sustained Juiciness	5.6^{ab}	5.9^{a}	5.9^{a}	5.4^{abc}	5.2^{abc}	5.4^{abc}	5.0^{bc}	5.4^{ab}	5.2^{abc}	4.7^{c}	5.1^{bc}	5.1^{bc}	0.1
Tenderness (first impression)	5.5^{a}	5.9^{a}	6.0^{a}	5.6^{a}	5.3^{a}	5.4^{a}	5.1^{a}	5.5^{a}	5.4^{a}	5.0^{a}	5.1^{a}	5.5^{a}	0.1
Tenderness (overall impression)	5.4^{a}	6.0^{a}	5.9^{a}	5.7^{a}	5.2^{a}	5.4^{a}	5.2^{a}	5.7^{a}	5.5^{a}	5.2^{a}	5.3^{a}	5.5^{a}	0.1
Amount of connective tissue	5.8^{a}	6.0^{a}	6.3^{a}	5.8^{a}	5.3^{a}	5.6^{a}	5.5^{a}	5.6^{a}	5.6^{a}	5.6^{a}	5.7^{a}	5.8^{a}	0.1

$^{a-c}$ Means within a row with the same letter are not different (P>0.05)

CON: Control (Bermudagrass), IND: Indiangrass, MIX: Mix of Native Warm Season Grasses

3.6 References

AMSA. (2012). Meat color measurement guidelines. American Meat Science Association, Champaign, Illinois, USA.

AMSA. (2012). Research guidelines for cookery, Sensory evaluation and instrumental tenderness measurements of fresh meat. *American Meat Science Association in cooperation with National Livestock and Meat Board*, 48

AOAC. (2000). Official methods of analysis (17th edition), 2nd Vol., Gaithersburg, MD, USA. Association of the Official Analytical Chemists.

AOAC (2007).Official methods of analysis (18th ed.) Arlington, VA, USA. Association of Official Analytical Chemists

Bidner, T. D., Schupp, A. R., Montgomery, R. E., &, Carpenter Jr, J. C. (1981). Acceptability of beef finished on all-forage, forage-plus grain or high energy diets. . *Journal of Animal Science, 62,* 381–387.

Brewer, P., & Calkins, C. (2003). Quality traits of grain- and grass-fed beef: a review. *Nebraska Beef Report, 2003*, 74-77.

Cox, R. B., Kerth, C. R., Gentry, J. G., Prevatt, J. W., Braden, K. W., & Jones, W. R. (2006). Determining acceptance of domestic forage-or grain-finished beef by consumers from three southeastern US states. *Journal of Food Science, 71*(7), S542-S546.

Daley, C. A., Abbott, A., Doyle, P. S., Nader, G. A., & Larson, S. (2010). A review of fatty acid profiles and antioxidant content in grass-fed and grain-fed beef. *Nutrition Journal, 9*(10)*,* 1-12.

Daniel, M., Dikeman, M., Arnett, A., & Hunt, M. (2009). Effects of dietary vitamin A restriction during finishing on color display life, lipid oxidation, and sensory traits of longissimus and triceps brachii steaks from early and traditionally weaned steers. *Meat Science, 81*(1), 15-21.

Dawson, L. E. R. (2012). The effect of inclusion of lupins/triticale whole crop silage in the diet of winter finishing beef cattle on their performance and meat quality at two levels of concentrates. *Animal Feed Science and Technology, 171*(2-4), 75-84.

Dikeman, M., Pollak, E., Zhang, Z., Moser, D., Gill, C., & Dressler, E. (2005). Phenotypic ranges and relationships among carcass and meat palatability traits for fourteen cattle breeds, and heritabilities and expected progeny differences for Warner-Bratzler shear force in three beef cattle breeds. *Journal of Animal Science, 83*(10), 2461-2467.

Duckett, S., Neel, J., Fontenot, J., & Clapham, W. (2009). Effects of winter stocker growth rate and finishing system on: III. Tissue proximate, fatty acid, vitamin, and cholesterol content. *Journal of Animal Science, 87*(9), 2961-2970.

Duckett, S. K., Neel, J. P. S., Sonon Jr, R. N., Fontenot, J. P., Clapham, W. M., & Scaglia, G. (2007). Effects of winter stocker growth rate and finishing system on: II. Ninth-tenth-eleventh-rib composition, muscle color, and palatability. *Journal of Animal Science, 85*(10), 2691-2698.

Dunne, P. G., Monahan, F. J., O'Mara, F. P., & Moloney, A. P. (2005). Colour stability, under simulated retail display conditions, of M. longissimus dorsi and M. semimembranosus from steers given long-term daily exercise and supplemented with vitamin E. *Meat Science, 71*(3), 480-489.

Ercolini, D., Ferrocino, I., Nasi, A., Ndagijimana, M., Vernocchi, P., La Storia, A., Laghi, L., Mauriello, G., Guerzoni, M. E., & Villani, F. (2011). Monitoring of microbial metabolites and bacterial diversity in beef stored under different packaging conditions. *Applied Environmental Microbiology, 77*(20), 7372-7381.

Ercolini, D., Russo, F., Torrieri, E., Masi, P., & Villani, F. (2006). Changes in the spoilage-related microbiota of beef during refrigerated storage under different packaging conditions. *Applied Environmental Microbiology, 72*(7), 4663-4671.

Feuz, D. M., Umberger, W. J., Calkins, C. R., & Sitz, B. (2004). US consumers' willingness to pay for flavor and tenderness in steaks as determined with an experimental auction. *Journal of Agricultural and Resource Economics*, 501-516.

French, P., O'Riordan, E. G., Monahan, F. J., Caffrey, P. J., Mooney, M. T., Troy, D. J., & Moloney, A. P. (2001). The eating quality of meat of steers fed grass and/or concentrates. *Meat Science, 57*(4), 379-386.

French, P., O'Riordan, E. G., Monahan, F. J., Caffrey, P. J., & Moloney, A. P. (2003). Fatty acid composition of intra-muscular triacylglycerols of steers fed autumn grass and concentrates. *Livestock Production Science, 81*(2–3), 307-317.

Gatellier, P., Mercier, Y., Juin, H., & Renerre, M. (2005). Effect of finishing mode (pasture-or mixed-diet) on lipid composition, colour stability and lipid oxidation in meat from Charolais cattle. *Meat Science, 69*(1), 175-186.

Harper, C. A. (2007). Native warm-season grasses: Identification, establishment and management for wildlife and forage production in the mid-south: a manual for natural resource professionals and other land managers: University of Tennessee, Extension Service.

Insani, E. M., Eyherabide, A., Grigioni, G., Sancho, A. M., Pensel, N. A., & Descalzo, A. M. (2008). Oxidative stability and its relationship with natural antioxidants during refrigerated retail display of beef produced in Argentina. *Meat Science, 79*(3), 444-452.

Kerth, C. R., Braden, K. W., Cox, R., Kerth, L. K., & Rankins Jr, D. L. (2007). Carcass, sensory, fat color, and consumer acceptance characteristics of Angus-cross steers finished on ryegrass (Lolium multiflorum) forage or on a high-concentrate diet. *Meat Science, 75*(2), 324-331.

Lage, J. F., Paulino, P. V. R., Filho, S. C. V., Souza, E. J. O., Duarte, M. S., Benedeti, P. D. B., Souza, N. K. P., & Cox, R. B. (2012). Influence of genetic type and level of concentrate in the finishing diet on carcass and meat quality traits in beef heifers. *Meat Science, 90*(3), 770-774.

Latimori, N., Kloster, A., Garcia, P., Carduza, F., Grigioni, G., & Pensel, N. (2008). Diet and genotype effects on the quality index of beef produced in the Argentine Pampeana region. *Meat Science, 79*(3), 463-469.

Lee, S., Decker, E., Faustman, C., & Mancini, R. (2005). The effects of antioxidant combinations on color and lipid oxidation in n−3 oil fortified ground beef patties. *Meat Science, 70*(4), 683-689.

Maher, S., Mullen, A., Moloney, A., Drennan, M., Buckley, D., & Kerry, J. (2004). Colour, composition and eating quality of beef from the progeny of two Charolais sires. *Meat Science, 67*(1), 73-80.

Mancini, R. A., Suman, S. P., Konda, M. K. R., & Ramanathan, R. (2009). Effect of carbon monoxide packaging and lactate enhancement on the color stability of beef steaks stored at 1°C for 9 days. *Meat Science, 81*(1), 71-76.

Martin, J., & Rogers, R. (2004). Review: Forage-produced beef: Challenges and potential. *The Professional Animal Scientist, 20*(3), 205-210.

Mathews Jr, K. H., & Johnson, R. J. (2010). Grain and grass beef production systems. *Washington: Economic Research Service, USDA, http://www.highlandcattleusa.org/content/Grain%20and%20Grass%20Beef%20Production%20Systems.pdf*.

Maughan, C., Tansawat, R., Cornforth, D., Ward, R., & Martini, S. (2012). Development of a beef flavor lexicon and its application to compare the flavor profile and consumer acceptance of rib steaks from grass- or grain-fed cattle. *Meat Science, 90*(1), 116-121.

Meilgaard, M., Civille, G. V., Carr, B. T. (2007). *Sensory Evaluation Techniques.* 4th ed. CRC Press, Boca Raton, FL, 275-279.

Moloney, A. P., Mooney, M. T., Troy, D. J., & Keane, M. G. (2011). Finishing cattle at pasture at 30 months of age or indoors at 25 months of age: Effects on selected carcass and meat quality characteristics. *Livestock Science, 141*(1), 17-23.

Muchenje, V., Dzama, K., Chimonyo, M., Strydom, P., Hugo, A., & Raats, J. (2009). Some biochemical aspects pertaining to beef eating quality and consumer health: A review. *Food Chemistry, 112*(2), 279-289.

Mumford, F. B. (1911). Fattening cattle on blue grass pasture: An investigation of the factors of age, condition, kind of ration and length of feeding period in beef production: University of Missouri, College of Agriculture, Agricultural Experiment Station. *http://books.google.com/books?id=nEKpXwAACAAJ.*

Pavan, E., & Duckett, S. K. (2013). Fatty acid composition and interrelationships among eight retail cuts of grass-feed beef. *Meat Science, 93*(3), 371-377.

Peel, D. S. (2011). Market coordination in the beef stocker sector: Short and long run implications of higher corn prices. *Southern Agricultural Economics Association annual meeting, Texas* (pp. 6-8). *http://ageconsearch.umn.edu/bitstream/98826/2/Market%2520Coordination%2520in%2520the%2520Beef%2520Stocker%2520Sectorx.pdf*

Pordomingo, A. J., García, T. P., & Volpi Lagreca, G. (2012). Effect of feeding treatment during the backgrounding phase of beef production from pasture on: II. Longissimus muscle proximate composition, cholesterol and fatty acids. *Meat Science, 90*(4), 947-955.

Pordomingo, A. J., Grigioni, G., Carduza, F., & Lagreca, G. V. (2012). Effect of feeding treatment during the backgrounding phase of beef production from pasture on: I. Animal performance, carcass and meat quality. *Meat Science, 90*(4), 939-946.

Priolo, A., Micol, D., & Agabriel, J. (2001). Effects of grass feeding systems on ruminant meat colour and flavour. A review. *Animal Research, 50*(3), 185-200.

Razminowicz, R. H., Kreuzer, M., & Scheeder, M. R. L. (2006). Quality of retail beef from two grass-based production systems in comparison with conventional beef. *Meat Science, 73*(2), 351-361.

Realini, C. E., Duckett, S. K., Brito, G. W., Dalla Rizza, M., & De Mattos, D. (2004). Effect of pasture vs. concentrate feeding with or without antioxidants on carcass characteristics, fatty acid composition, and quality of Uruguayan beef. *Meat Science, 66*(3), 567-577.

Resconi, V. C., Escudero, A., Beltrán, J. A., Olleta, J. L., Sañudo, C., & Mar Campo, M. d. (2012). Color, lipid oxidation, sensory quality, and aroma compounds of beef steaks displayed under different levels of oxygen in a modified atmosphere package. *Journal of Food Science*, *71*(1)*,* S10-S18.

Schaake, S., Skelley, G., Halpin, E., Grimes, L., Brown, R., Cross, D., & Thompson, C. (1993). Carcass and meat sensory traits of steers finished on fescue and clover, summer forage, or for different periods in drylot. *Journal of Animal Science, 71*(12), 3199-3205.

Schilling, M. W., A. Pham. 2012. Sensory evaluation of muscle foods. Pages 207-224 in Y.H. Hui, editor, Handbook of meat and meat processing, CRC Press, Boca Raton, Florida.

Schmidt, T. B., Schilling, M. W., Behrends, J. M., Battula, V., Jackson, V., Sekhon, R. K., & Lawrence, T. E. (2010). Use of cluster analysis and preference mapping to evaluate consumer acceptability of choice and select bovine M. *Longissimus Lumborum* steaks cooked to various end-point temperatures. *Meat Science, 84*(1), 46-53.

Sitz, B., Calkins, C. R., Feuz, D. M., Umberger, W. J., & Eskridge, K. M. (2005). Consumer sensory acceptance and value of domestic, Canadian, and Australian grass-fed beef steaks. *Journal of Animal Science, 83*(12), 2863-2868.

Stelzleni, A. M., & Johnson, D. D. (2008). Effect of days on concentrate feed on sensory off-flavor score, off-flavor descriptor and fatty acid profiles for selected muscles from cull beef cows. *Meat Science, 79*(2), 382-393.

Suman, S., Mancini, R., Joseph, P., Ramanathan, R., Konda, M., Dady, G., & Yin, S. (2010). Packaging-specific influence of chitosan on color stability and lipid oxidation in refrigerated ground beef. *Meat Science, 86*(4), 994-998.

Vanderzant, C., & Splittstoesser, D. (1992). Compendium of methods for the microbiological examination of foods. 3rd ed. 88-89, Edwards Brothers, Ann Arbor, MI.

Vestergaard, M., Oksbjerg, N., & Henckel, P. (2000). Influence of feeding intensity, grazing and finishing feeding on muscle fibre characteristics and meat colour of semitendinosus, longissimus dorsi and supraspinatus muscles of young bulls. *Meat Science, 54*(2), 177-185.

Yang, A., Lanari, M. C., Brewster, M., & Tume, R. K. (2002). Lipid stability and meat colour of beef from pasture- and grain-fed cattle with or without vitamin E supplement. *Meat Science, 60*(1), 41-50.

Yin, M. C., Faustman, C., Riesen, J. W., & Williams, S. N. (1993). α-Tocopherol and ascorbate delay oxymyoglobin and phospholipid oxidation in vitro. *Journal of Food Science, 58*, 1273-1276.

CHAPTER IV

THE EFFECT OF FEEDING NATIVE WARM SEASON GRASSES DURING THE STOCKER PHASE ON THE MEAT COMPOSITION, QUALITY CHARACTERISTICS, AND SENSORY PROPERTIES OF LOIN STEAKS FROM FORAGE-FINISHED CATTLE

4.1 Introduction

Cattle were generally grazed on forages during the early to mid-1900s (Johnson, 2010, and Martin & Rogers, 2004). Since this time, farmers have adopted more centralized methods for raising cattle by feeding them at one place in close proximity to the harvesting site. The introduction of grain feeding started in the early 20th century where cattle were fed grain so that they would be ready for harvest in a shorter period of time (Johnson, 2010). The current practice of finishing cattle on grain is for approximately 100 days (Schmidt, et al., 2010). However, forage systems are still the most common method for feeding cattle in different parts of the world including the United States (Thomas, et al., 2011), where cattle are fed forages in the stocker phase (Scaglia, et al., 2012). According to the USDA outlook report 2010 (USDA, 2010), there is a niche market (3% of the U.S. beef market) for grass-finished beef, which is increasing at approximately 20 % each year. Although forage finishing can lead to darker colored meat, less marbling, off-flavors associated with forages, and less tender meat

(Kerth, et al., 2007), researchers have reported that feeding high quality forages and proper grazing management can produce beef which is comparable to that of grain finished beef (French, et al., 2001, Latimori, et al., 2008 and Realini,et al., 2004). In addition, forage-finished beef is sold for premium prices (Cox, et al., 2006) since consumers perceive that forage-finished beef is more natural than grain finished beef. In addition, researchers have reported that cattle that were finished on forage had low inputs which increased the profits of farmers (Razminowicz, et al., 2006). Cattle fed on forages have leaner meat (lower intramuscular fat content) that differs in lean and color characteristics when compared to grain-finished cattle at a similar degree of external finish. Previous studies have indicated that 20% (51 out of 248 participants from Chicago and San Francisco) of consumers who participated in the studies were willing to pay more for grass finished steaks when compared to grain-finished steaks (Sitz, et al., 2005, and Umberger, et al., 2003). This indicates that there is a niche market in some highly populated areas that could be more fully capitalized on as an outlet for forage finished beef.

Suppositions have been made in previous research that there is a potential market for grass finished beef due to the production of leaner and healthier meat (Umberger, et al., 2009). It has been reported that forage finished beef has conjugated linolenic acid and a higher ratio of n-3 to n-6 fatty acids than grain-finished beef. However, the actual amounts of n:3 fatty acids may not be greater in forage finished beef since grain-finished beef has a higher total fat percentage (Razminowicz, et al., 2006, Leheska, et al., 2008, and Garcia, et al., 2008). Forage systems in the South include 24 million ha of perennial forages and 8 million ha of annual forages (Ball & Lacefield, 2007).

In the Southeastern United States, warm season grasses are found in abundance (Burns, 2011). Native warm season grasses that naturally grow in the South, can be used as forage for beef cattle, and is a better habitat for wildlife when compared to bermudagrass (Burns, 2011). Generally in the south, cattle are fed bermudagrass in the stocker phase during the summer months. However, Kallenbach et al. (2012) reported that the average daily weight gains when bermudagrass was fed was 0.75 kg as compared to native warm season grasses which was 1.25 kg per day.

Research was conducted to test the effects of feeding native warm season grasses in the stocker phase and finishing on tall fescue on carcass quality, meat quality and sensory properties. This was determined by evaluating differences in beef quality between *longissimus* (loin) steaks from cattle that were grazed on either bermudagrass or native warm-season grasses in the stocker phase and finished on tall fescue. Beef quality was evaluated through proximate composition, fatty acid profile, color, tenderness, lipid oxidation, cooking loss, sensory testing, yield grade, and quality grade.

4.2 Materials and Methods

4.2.1 Sample Collection

Animals (n=225) were grazed on three summer forage treatments (CON, Bermudagrass; IND, Indian monoculture; MIX, Mix of native warm season grasses (Mix sward of Indiangrass, Big bluestem and Little bluestem)). This project was conducted at the MAFES (Mississippi Agriculture and Forestry Experiment Station) Prairie Research Unit starting May 2011. Cattle were allotted to three different forage treatments which were replicated three times; eight animals were allotted to each replicate pasture plot within a treatment. Cattle (6 to 7 months old) grazed on these forages until winter and

were fed a baleage of sudangrass during winter. Cattle were grazed on tall fescue in spring and summer until they reached the harvest weight. Eighteen animals were selected from these cattle (6 per treatment) for the forage-finished study and were harvested in June 2012. Short loin wholesale cuts were removed from each carcass, vacuum packaged and aged for two weeks prior to fabrication. After aging, wholesale loins were fabricated into 1 inch steaks.

4.2.2 Meat Quality Analyses

Steaks were subjected to simulated retail display by placing them on styrofoam trays with soaker pads (Cryovac processor 3S trays yellow, Sealed Air, SC, USA) and overwrapping with an oxygen permeable PVC film (O2 permeability 780 cc/100 in 2/day; water permeability 14 g/100 in 2/ day; PVC Stretch Film, LINPAC Packaging – Filmco, Inc., U.S.A.). Steaks were stored under lights (Cool White 34 Watt, Sylvania Supersaver Ecologic, Danvers, MA) under refrigerated conditions (2 ºC at 800 lux) for 0, 3, and 6 days. Six steaks from each treatment were analyzed for color, pH, and lipid oxidation on the respective storage days. Separate steaks were used to determine proximate composition. Steaks that were displayed under lights for 0 day of storage were utilized for cooking loss and instrumental tenderness measurements. Nine steaks from each treatment were collected on day 0 and frozen at -20°C for sensory analyses that were conducted within 3 months of harvesting cattle. In addition, steaks that were displayed for 0 days of storage were also utilized to determine fatty acid profiles.

4.2.3 Proximate Composition

Steaks (six per treatment, n=18) that were stored under light for 0 days were selected to determine moisture, fat, and protein content using a Near Infrared Spectrometer (NIR) (FoodScan Lab Analyzer Model 78810, FOSS Analytical A/S, Slangerupgade, DK, AOAC, 2007). Two steaks were obtained from each treatment for each replication prior to storage and separately analyzed for proximate composition. Fresh meat was ground with a meat grinder (Cabela's PRO 450, Cabela's, Sidney, NE) that was fitted with a 3-mm (1/8 inch) grinder plate. Ground samples were tightly packed into a 140-mm sample cup prior to analysis and were analyzed using the NIR.

4.2.4 Meat Color

At each refrigerated storage time (0, 3, and 6 days), the color of beef steaks (n=6 per treatment) was measured using a chroma meter with a D-65 illuminant and an aperture size of 50 mm (Model CR-410, Minolta Camera Co., Ltd., Osaka, Japan Serial No C8202489) that was calibrated using a standard white calibration plate (Model No 20933026, Japan). Two steaks from each treatment, within each replication, were used to measure instrumental meat color (expressed as CIE L*, a*, b*, hue, and chroma values). The color attributes were measured at four identical locations on each steak and averaged at 0, 3, and 6 days of storage respectively. The bloom time was 60 min between fabrication and the packaging of steaks. The steak samples were removed from the packages on each day of storage and color attributes were measured on each steak using a hand held chroma meter. The values were recorded for each steak and averaged for final reporting.

4.2.5 Meat pH

The pH of two steaks from each treatment, within each replication was determined after 0, 3, and 6 days of refrigerated storage using an Accumet pH meter (Model Accumet 61, Fisher Scientific Hampton, NH, USA) with a meat penetrating pH probe (FlexipHet SS Penetration Tip, Cole Palmer, Vernon Hills, IL) that was calibrated with pH standards of 4.0 and 7.0. A pH penetrating probe which was attached to a pH meter was used by inserting the pH probe into the steak samples and values were recorded. For each steak, two measurements were recorded and averaged for final reporting.

4.2.6 Thiobarbituric Acid Reactive Substances

Lipid oxidation of beef steaks was determined using a Thiobarbituric acid reactive substances (TBARS) assay and expressed as milligrams of malonaldehyde per kilogram of sample (Yin, 1993). Two steak samples were selected at 0, 3, and 6 days of storage for TBARS measurements from each replication for each of the 3 treatments. The same steaks that were used for color and pH analysis were used to determine TBARS. Five g samples from each steak were weighed in duplicate from different portions of the steak, mixed with 11% trichloroacetic acid, homogenized in a blender (Osterizer Galaxie, Oster Corporation, Milwaukee, WI) and filtered using Whatman filter paper no. 1. Two ml of filtrate was then mixed with 2 ml of 20 mM thiobarbituric acid and incubated at 25 ºC for 20 h. Absorbance of the solution was recorded at 532 nm and the concentration of MDA mg/kg was calculated using a standard curve. At each storage time, six samples per treatment were analyzed.

4.2.7 Aerobic Plate Count

Aerobic plate count was determined for beef steaks using a method described by Vanderzant & Splittstoesser (1992). The same steaks that were used for color, pH and lipid oxidation measurements were also used to determine aerobic plate count at each storage time. Microbial determination was conducted prior to any other analysis at each storage time (0, 3, and 6 days) to avoid any contamination while determining other meat quality parameters such as pH, color and lipid oxidation. A 10 g sample was taken in duplicate from each steak under aseptic conditions and 90 ml of 0.1% sterilized peptone water was added to the sample in a stomacher bag. Sample bags were stomached for 45 s in a stomacher (Whirl-Pak, Nasco, Fort Atkinson, WI, USA) and subsequent serial dilutions were made in 0.1% peptone water. Up to four dilutions were prepared and plated the aerobic plate counts. Dilutions which had countable colonies (between 1-300 colonies) were selected to calculate CFU per g of sample. The aerobic plate count was determined by spread plating 1 ml of homogenate on the APC petrifilm (3M Petrifilm Aerobic Count Plates, 3M, MN, USA). Plates were incubated aerobically (37 °C) for 48 h prior to colony counting. APC was reported as $\log_{10}$ of colony forming units (CFU) per g.

4.2.8 Fatty Acid Profile

4.2.8.1 Sample Preparation

For fatty acid profile determination, three previously frozen steaks per treatment were thawed out at 2 °C for 24 h. Enough sample (approximately 300g) was taken so that thirty to fifty grams of fat was extracted out of the meat sample into a mojonnier flask. To each sample flask, 1 ml of chloroform containing Triundecanoin (10mg/ml), a hydrochloric acid-water mixture (70:30), 2 ml ethanol and 100 mg of pyrogallolic acid

were added and samples were placed in a shaking water bath at 75 °C for 40 min. Samples were extracted first using diethyl ether and then petroleum ether; both ether extracts were collected into a 250 ml beaker with boiling beads and then gently boiled in a steam bath to dryness. Four ml of 0.5N NaOH in methanol and 10 ml of hexane was added to the beaker prior to transfer to a 125 ml flat-bottom flask with a ground glass joint that was attached to a condenser. The solution was boiled and refluxed gently until the fat was dissolved. Five ml of borontrichloride in methanol was added and boiled for 2 min. This liquid was transferred to a 125 ml separatory funnel, and 15 ml of saturated aqueous NaCl solution was added. The mixture was shaken, and the bottom layer was discarded. The top layer was retained and was dried by passing the isooctane layer through granular sodium sulphate. The filtrate was collected, and the volume was adjusted to 10 ml. Prior to GC analysis, a 1:10 dilution was made with hexane.

4.2.8.2 Gas Chromatography Analysis

Fatty Acid Methyl Esters (FAME) were analyzed using a modified method (AOAC 996.06, 17th edition, AOAC, 2000, 2000a, 2000b) for a GC/ FID (Varian 3400 gas chromatograph with a flame ionization detector, a Model 8200 Varian autosampler, CA, USA), and a sol gel wax column (30 meter x 0.25 mm ID x 0.25 mm phase thickness). The program was initiated at 50 °C for 3 min and subsequently ramped to 220°C at 4 °C/min increments. The injector and detector were maintained at 200 °C and 300 °C, respectively. The injection volume was 1 µl and the column gas flow was 1 ml/min. Hydrogen was used as the carrier gas at a flow rate of 30 ml/min. The fatty acids were identified by comparing retention times with standards. The fatty acid percentages were calculated from the total fatty acids that were determined.

4.2.9 Cooking Loss

Two frozen steak samples from each replication were used from each treatment. Samples were thawed at 2°C overnight prior to cooking. After determining raw weights, steaks were roasted at 177°C in an oven (JBP25DOJ2WH, General Electric, Louisville, KY) to a final internal temperature of 71°C. Internal steak temperatures were assessed using meat thermocouples (thermocouple type-T connected with UWTC-1 connectors and wireless RF receiver UWTC, Omega Engineering, Inc., Stamford, CT, U.S.A.) by inserting the thermocouples into the thickest portion of each steak sample. Cooked steak samples were removed and allowed to rest for an hour to equilibrate to a room temperature. Residual moisture was removed from each sample with a paper towel by blotting for 10 s prior to reweighing. Cooking loss was reported as a percentage and calculated as follows:

$$\% \text{ cook loss} = [(\text{raw weight} - \text{cooked weight})/ \text{raw weight}] \times 100 \quad (4.1)$$

4.2.10 Instrumental Tenderness

Instrumental tenderness was determined for six steaks per treatment (two steaks per replication) using a procedure described by Schmidt et al., (2010). Frozen steaks for each treatment were thawed at 4°C for 20 h. Each steak was cooked as described in the cooking loss section. Steaks were then allowed to cool to approximately 20 °C (ambient temperature) and 6-8 cores (12.7 mm diameter) were removed parallel to the muscle fibers for each steak. Cores were sheared perpendicular to the muscle fibers using a Warner–Bratzler shear attachment that was mounted to an Instron Universal Testing Center (Model 3300, Instron, Norwood, MA, USA) using a 500 N load transducer and a

cross-head speed of 200 mm/min. The average for maximum peak force was calculated for each steak and treatment means were reported as Warner Bratzler shear force (N).

4.2.11 Consumer Acceptability

Three consumer based sensory panels (n=180) were conducted to evaluate the acceptability of beef steaks. The participants consisted of students, staff and faculty at Mississippi State University. Samples (two per rep and six per treatment) were cooked as described for cooking loss and tenderness determinations. Steak samples were cooked to an internal temperature of 71 °C, cooled for 15 min, cut into 2.54 cm cubes and stored in a covered chafing dish (60 °C) until panelists evaluated the samples (AMSA, 2012). Labeled plastic cups with lids (Sweetheart Cup Co., Owning Mills, MD) with random three-digit numbers were used to identify each sample, and each participant evaluated three treatment samples in a booth under red light. Participants were asked to evaluate overall acceptability and acceptability in respect to appearance, texture and flavor on a nine point hedonic scale in individual booths (Meilgaard, et al., 2007). The scale was categorized as: nine=like extremely, eight=like very much, seven=like moderately, six=like slightly, five=neither like nor dislike, four=dislike slightly, three=dislike moderately, two=dislike very much, one-dislike extremely. Acceptability of texture was defined as product liking in respect to tenderness. Acceptability of appearance was defined as product liking in respect to color and visible moisture, and acceptability of flavor was defined as product liking in respect to beef flavor (taste). Panelists were asked to evaluate all attributes for each sample before evaluating the next sample, and to evaluate one sample at a time going from left to right on the score sheet. Sample order was also randomized to account for sampling order bias. Panelists evaluated beef samples

that were coded with a random 3 digit numbers and recorded their responses using compusense software (compusense five, Compusense Inc. Guelph, Ontario, Canada). Water, apple juice and unsalted crackers were provided, and panelists were asked to expectorate and rinse their mouths with apple juice between each sample.

4.2.12 Descriptive Analysis

For descriptive analysis of the steak samples, eight panelists with an average of 50 hrs of previous experience evaluating meat products were trained for 5 to 10 h according to AMSA (AMSA 2012, Meilgaard, et al., 2007 and Schilling & Pham, 2012) guidelines. Three samples were cooked at each evaluation time from each treatment with three replications and three samples from each treatment presented to panelists on the respective days. The following scale was used for evaluating myofibrillar and overall tenderness, 1 = extremely tough and 8 = extremely tender (AMSA, 2012). For the amount of connective tissue that was present in the sample, the following scale was used: 1 = abundant and 8 = none. For initial and sustained juiciness, an eight-point hedonic scale was used where 1 = extremely dry and 8 = extremely juicy. Additional training sessions were performed to train panelists with respect to beef aroma, beef flavor, flavor intensity, bloody (flavor associated with under-cooked meat), metallic, brown/burnt, liver, and roasted. To each be evaluated using a fifteen point scale line (0 = none for the descriptor and 15 = maximum intensity) (Maughan, et al., 2012). Samples were cooked as described in the cooking loss section, cut into 2.54 cm cubes and evaluated by an eight-member trained sensory panel (AMSA, 1995). Steak pieces were served in 2 oz. plastic containers (Sweetheart Cup Co., Owing Mills, MD) that were coded with random three-digit numbers. Four sessions were conducted for descriptive sensory analysis of beef steaks,

one session on each day of display time period. The order of presentation of the samples was randomized to prevent bias. Panelists were provided with water, apple juice and expectorant cups to cleanse their palate between sample evaluations.

4.2.13 Statistical Analyses

A completely randomized design with 3 treatments, 3 replications , and 2 subsamples per treatment (n=18) was utilized to test the effects of diet on the proximate composition, tenderness, and fatty acid profile of *Longissimus* steaks (Statistical Analysis Software, version 9.1, SAS Institute, Cary, NC). In addition, a factorial structure within the completely randomized design was utilized to evaluate pH, color, lipid oxidation, and sensory characteristics since steak samples were analyzed over storage time from each dietary treatment. When differences existed among treatments ($P<0.05$), the Fisher's Protected Least Significant Difference (LSD) test was used to separate treatment means. For the preference and liking of the beef steaks, agglomerative hierarchical clustering using Wards Method (XL Stat 2006) was performed to group panelists together based on preference and liking of steak samples. The panelists were grouped into clusters based on a dissimilarity plot and a dendrogram. After separating the data into clusters, the entire data set was evaluated to confirm that the data for each panelist was relatively close to the means of the treatments that were within the cluster that they were grouped into. After conducting agglomerative hierarchical clustering, randomized complete block designs (panelists as blocks) were used within each cluster, and Fisher's protected LSD test was utilized to separate treatment means within a cluster when differences occurred ($P<0.05$).

4.3 Results and Discussion

4.3.1 Carcass Quality

Bermudagrass (CON) and mixed native warm season grass (MIX) treatments yielded 17% select carcasses and 83% standard carcasses, while cattle from the Indiangrass (IND) treatment yielded 67% select carcasses and 33% standard carcasses (Table 4.1). The quality grade depends on the degree of marbling and maturity of each carcass. According to the literature, medium framed cattle of all breeds can grade select or higher when finished on forage (Scaglia, et al., 2012). In the current research, the degree of marbling was slight and traces which is normal for early maturity cattle. In addition, these carcasses graded out at select or standard, which is also normal for forage finished cattle (Scaglia, et al., 2012). No difference ($P>0.05$) existed in yield grades between the treatments with all treatments having an average yield grade of 2.2 Cox et al. (2006) and Neel et al. (2007) reported similar values for yield and quality grade for forage finished beef. The sample is too small to make definitive conclusions, but results indicate that feeding with Indiangrass may contribute to an increase in select carcasses when compared from standard carcasses fed bermudagrass (CON) or mixed native warm season grass (MIX).

4.3.2 Proximate Composition

The proximate composition of strip loin steaks did not differ ($P>0.05$) between treatments (Table 4.1). The average moisture content in beef steaks was 73%, and the average protein percentage was 22.5. The fat content was 2.4 % on an average, which is normal for the intramuscular fat content of standard and select steaks. Strip loin steaks from the IND grass treatment had 2.6 % fat. This slight difference in fat percentage may

be why Indiangrass yielded a greater percentage of select carcasses when compared to MIX and CON treatments. In our study on grain finished cattle, there was a major difference in fat percentage and only a slight difference in moisture percentage (chapter 3). Pavan & Duckett, (2013) and Pordomingo et al. (2012) reported similar values for protein, fat and moisture percentage in *longissimus* muscle for forage finished (tall fescue for 200 d) cattle as compared to results from this study. Fat percentage was 3.2% which was a little higher than the current study. This can be attributed to a longer feeding time on forage. Moisture (73%) and protein (23.3) values were also similar to results from the current study.

4.3.3 Meat Color

CIE L*, a*, b*, chroma, and hue did not differ ($P>0.05$) between strip loin steaks from each treatment at each storage time with the exception of a* and hue on day 6 of storage (Table 4.2). Redness is a major determinant of consumers retail purchasing decisions (Umberger, et al., 2009). Redness of strip loin steaks had an average value of 26 at day 0 and 25 after 3 days of storage. Scaglia et al. (2012) reported a* values of 27 and 25 for *longissimus* muscle that were grain finished and a* values of 25 and 24 for forage finished (alfalfa) cattle that were fed tall fescue. Discoloration of beef steaks was visible on day 6 when values for redness decreased ($P<0.05$) to an average of 20 for all treatments. Although a* and hue were numerically different ($P<0.05$) on day 6, these differences were considered of little practical significance. Display storage in aerobic packaging and under lights influences the color stability of beef steaks. Oxygenation of myoglobin results in a change in the color of beef steaks. When a muscle is fresh and is not exposed to air or oxygen, it is in the deoxymyoglobin state which is indicated by a

purplish color. Soon after exposure to a high concentration of oxygen, the surface of the steak converts to a red color due to the formation of oxymyoglobin. After 3 to 6 days of aerobic storage, the meat surface pigment is converted to metmyoglobin due to oxidation of Fe^{2+} to Fe^{3+} which results in brown discoloration of the meat surface. Similarly, the chroma values of steaks after 0 days of retail storage were greater ($P<0.05$) than chroma values after 6 days of storage for IND and MIX treatments, indicating a decrease in color intensity as storage time increased. The color of beef steaks depends on many factors including diet, age and the amount of stress undergone by the animal during harvesting and ultimate pH (Campo, et al., 2008 and Priolo, et al., 2001). Redness of forage-finished steaks was in an acceptable range at 0 and 3 days of storage with a* values of 25 to 26, Mancini et al. (2009), and Scaglia et al. (2012)) also reported average values of 27. The values reported in the literature for grass finished beef are less than 20, which is less red and darker than grain finished beef (Yang, et al., 2004, and Duckett, et al., 2007). However, Scaglia et al. (2012) reported a* values for grass finished steaks averaging 24 which is in agreement with our results. Resconi et al. (2012) reported lower values for L* since the values were measured after opening the steaks from vacuum packages, and the myoglobin was still in the deoxymyoglobin state. In our study, a bloom time of 1 hour was allowed before the steaks were packaged with aerobic film which contributed to a slightly lighter color. Chroma value is the measure of color intensity by which strong and weak colors are recognized which is also called color saturation (AMSA, 2012). Our results showed a decrease ($P<0.05$) in chroma values after 6 days of retail display.

4.3.4 Meat pH

No differences existed (P>0.05) between any treatments or storage times with respect to pH (Table 4.3). The average pH values were in the normal range of 5.7-5.8. In contrast to our results, the ultimate pH were reported to be higher for grass finished beef by French et al. (2000) and Razminowicz et al. (2006) because of a stress response that leads to a high pH (>6.1) and dark color meat. Forage-finished cattle are less prone to penning and handling which sometimes leads to increased handling and transportation stress during harvesting which leads to increased pH.

4.3.5 Thiobarbituric Acid Reactive Substances

The most evident difference that existed (P<0.05) between the treatments for strip loin steaks in the current study was higher lipid oxidation (TBARS) values for steaks from the CON treatment when compared to steaks from the IND and MIX treatment (Table 4.3). Steaks from IND and MIX treatments had less (P<0.05) lipid oxidation on day 6 of storage when compared to the CON treatment. In addition, steaks from the IND and CON treatments had lower (P<0.05) TBARS values on day 3 than steaks from the MIX treatment, but the values were low with respect to TBARS values. Realini et al. (2004) reported the TBARS values in *longissimus* steaks to be more than 0.4 on day 12 of storage, which is regarded as a threshold value for noticeable lipid oxidation in the product. Lipid oxidation is responsible for the formation of end products which impart rancid off-flavors, thus indicating decreased meat quality (Yang, et al., 2002).

4.3.6 Aerobic Plate Count

The microbial load (aerobic plate count) did not differ (P>0.05) between treatments at any storage time (Table 4.3). However, aerobic plate count increased (P<0.05) from 3 to 5 log cfu from day 0 to day 6 of storage across all the treatments. Strip loin steaks analyzed after day 6 showed colony counts greater than 7 logs. Because of the higher percentage of moisture and protein in the steaks from the current study when compared to concentrate finished beef (chapter III), microbial load on steaks increased at a higher rate and the microbial shelf life was limited to 6 days of retail display. This is in contrast to the forage finished samples that did not spoil through 9 days of storage (Chapter III). This difference may be due to the high protein and moisture percentage in the forage finished steaks when compared to the grain finished steaks. These results indicate that microbial growth and oxidation over time contributed to the end of shelf-life, but the end of shelf life was mainly due to browning from metmyoglobin formation with lipid oxidation contributing to the end of shelf-life in steaks from the CON treatment.

4.3.7 Instrumental Tenderness and Cooking Loss

No differences existed (P>0.05) in shear force among treatments. The average shear force values were 28 N (Table 4.3). Schmidt et al. (2010) reported that shear force values below 30 N are very tender which supports the premise that forage finishing cattle can produce tender beef. Steaks from the IND treatment had less (P<0.05) cooking loss (22.1 %) than steaks from the MIX treatment (23.9 %), but there was no difference (P>0.05) in cooking loss between steaks from the MIX and CON treatments, with values of 23.0 % and 23.9 % respectively. Cook loss depends partially upon the amount of

intramuscular fat present in a steak. Our results were similar to Schmidt et al. (2010) who reported a cook loss percentage of 24.9% for select steaks when cooked to a medium (71°C) degree of doneness which is very similar to the results in our study. Other studies reported that forage finished beef was less tender than grain finished beef (Razminowicz, et al., 2006).

4.3.8 Fatty Acid Profile

No differences existed (P>0.05) in fatty acid composition among the steaks from all treatments (Table 4.4). Though no statistical differences existed among treatments for linolenic acid, steaks from IND may have had less lipid oxidation at day 6 than CON due to a lower numerical percentage of linolenic acid. Daley et al. (2010) and Realini et al. (2004) reported similar values in Angus cattle that were forage finished. The major focus for grass finished cattle is the unsaturated fatty acids, specifically conjugated linolenic acid and alpha linolenic acid that tend to be higher in grass finished beef when compared to grain finished beef. Our results were similar to the values given by Descalzo et al. (2005), and Realini et al. (2004). The fatty acids reported in *longissimus* muscle by Pavan & Duckett (2013) were similar to the results reported in our study. The polyunsaturated fatty acids PUFA (16:1+18:1+18:2+18:3) percentage was 39.2 for forage finished steers reported by Pavan & Duckett. (2013) which was in agreement with results from the current study where PUFA percentage was 39.6%. The distribution of monounsaturated fatty values acids reported by Duckett et al. (2009) were in agreement with our results for the average values of C14:0, C15:0, C16:0 and C17:0. These researchers also reported values for C18:1 cis to 34 on average for grain finished and 29 for forage finished beef which is also similar to the results from the current study.

4.3.9 Consumer Acceptability

On average, consumers rated beef strip loin steaks from all treatments between like slightly and like moderately (Table 4.5). No difference existed ($P>0.05$) between the treatments for overall acceptability. However, there was a slightly greater numerical value for overall acceptability of the IND treatment when compared to the other two treatments. Consumers were grouped into clusters (Schilling & Coggins, 2007) based on consumer ratings for preference and liking of loin steaks (Table 4.6). Cluster I consisted of 57 % of the consumers. This group rated beef steaks as like moderately and no difference ($P>0.05$) existed between the treatments. Cluster 2 consisted of 15 % of consumers; these consumers preferred ($P<0.05$) steaks from the MIX treatment over steaks from IND and CON but did not have high ratings for any of the steaks. This may have been due to these consumers not liking steaks that were cooked in the oven or cooked without spices. Cluster 3 contained 17 % of the panelists, who liked beef steaks and rated them either like moderately or between like very much and like extremely. Consumers in this group preferred ($P<0.05$) steaks from the IND and MIX treatments over steaks from CON, with no difference ($P>0.05$) between the steaks from MIX and IND treatments. Cluster 4 consumers (11.4%) preferred ($P<0.05$) steaks from the CON and IND treatments over steaks from the MIX treatment. Overall, almost 70 % of consumers rated beef steaks between like moderately and like extremely. Maughan et al. (2012) reported that the liking of beef steaks from forage finished cattle was between like slightly and like moderately which was in agreement with the current study. This indicates that feeding IND and MIX (NWSG) can be successfully included in the stocker phase which results in acceptable beef quality and may contribute to the production of

slightly more acceptable strip loin steaks when compared to cattle that are fed bermudagrass during the stocker phase when all cattle are finished on tall fescue.

4.3.10 Descriptive Sensory Analysis

Minimal differences ($P>0.05$) existed between the sensory descriptors of steaks at each storage time. However, rancid aroma increased for IND and CON treatments from day 0 to day 6 and rancid flavor increased from day 0 to day 6 for the CON and MIX treatments (Table 4.7). The flavor attributes for grass finished beef were derived by the flavors described by Maughan et al. (2012). Flavor in beef is dependent upon many factors such as diet, aging, oxidation, and lipid content (Calkins & Hodgen, 2007). Major changes in flavor occurred on day 6 of storage when lipid oxidation contributed to the development of off-flavors due to the formation of secondary oxidation compounds such as aldehydes and ketones.

4.4 Conclusions

There were minimal differences in the quality of forage-finished beef from treatments. Most of the carcasses were graded as standard for CON and MIX treatments. The cattle from IND treatment had higher percentage of select grade carcasses. The slightly higher percentage of fat in IND treatment was likely responsible for more select grade carcasses. The steaks from all the treatments did not differ for color, pH and instrumental tenderness. However, steaks from the CON treatment had higher TBARS values on day 6 of storage which indicates that steaks from the CON treatment had higher lipid oxidation when compared to steaks from IND and MIX treatments. Also, treatment IND had less cooking loss when compared to CON and MIX treatments. Consumers

rated beef steaks from all the treatments between like slightly and like moderately. This indicates that beef from forage finished cattle were acceptable among consumers. The descriptive sensory evaluation by trained panelists showed no difference for steaks between the treatments. The overall result obtained in the forage finished study indicates that forage finished beef was acceptable among the consumers and had a storage period of 6 days. Finishing cattle on forages did not alter the quality of beef steaks. Since NWSG are abundant in the southeastern United States, farmers can better use these grasses to feed cattle during the stocker phase. Future studies on beef obtained from cattle fed NWSG can be targeted towards willingness to pay models by consumers.

4.5 Tables

Table 4.1 Carcass quality (%) and proximate composition (%) of beef loin steaks from cattle that were fed bermudagrass and native warm season grass

Attribute	CON (%)	IND (%)	MIX (%)	SEM
Quality Grade				
Select +	16.7	16.7	-	
Select -	-	50	16.7	
Total select	**16.7**	**66.7**	**16.7**	
Standard +	83.3	33.3	83.3	
Standard -	-	-	-	
Total Standard	**83.3**	**33.3**	**83.3**	2.8
Yield Grade	2.2[a]	2.1[a]	2.3[a]	0.1
Proximate Composition				
Protein (%)	22.6	22.7[a]	22.9[a]	0.06
Fat (%)	2.4[b]	2.6[a]	2.2[b]	0.1
Moisture (%)	73.6[b]	73[a]	73.3[a]	0.1
Collagen (%)	1.4[a]	1.4[a]	1.3[a]	0.1

[a-c] Means within a row with the same letter are not different (P>0.05)
CON: Control (Bermudagrass), IND: Indiangrass, MIX: Mix of native warm season grasses
SEM Standard error of means

Table 4.2 Color attributes of beef loin steaks from cattle that were fed bermudagrass and native warm season grass during the stocker phase that were stored under simulated refrigerated retail display for 0, 3, and 6 days

Attribute	Treatment	Day 0	Day 3	Day 6	SEM
L* value	CON	38.5^{aX}	37.8^{aY}	38.4^{aX}	
	IND	39.4^{aX}	39.4^{aY}	39.3^{aX}	
	MIX	41.3^{aX}	41.5^{aX}	40.2^{aX}	0.4
b* value	CON	10.3^{aX}	10.5^{aX}	8.6^{aX}	
	IND	10.3^{aX}	10.2^{aX}	8.6^{aX}	
	MIX	11.3^{aX}	10.7^{abX}	8.6^{bX}	0.3
a* value	CON	25.1^{aX}	25.3^{aX}	20.7^{bX}	
	IND	24.9^{aX}	24.6^{aX}	19.6^{bY}	
	MIX	26.7^{aX}	25.4^{aX}	20.3^{bXY}	0.2
Chroma	CON	27.2^{aX}	27.4^{aX}	22.4^{aX}	
	IND	27.0^{aX}	26.6^{aX}	21.5^{bX}	
	MIX	29.0^{aX}	27.5^{aX}	22.1^{bX}	0.6
Hue	CON	22.1^{aX}	22.5^{aX}	22.3^{aY}	
	IND	22.2^{bX}	22.4^{bX}	23.9^{aX}	
	MIX	23.1^{aX}	22.9^{aX}	23.0^{aXY}	0.2

$^{a-c}$ Means within a row a with the same letter are not different (P>0.05)
$^{X-Z}$ Means within a column within an attribute with the same letter are not different (P>0.05)
CON: Control (Bermudagrass), IND: Indiangrass, MIX: Mix of native warm season grasses
SEM Standard error of means

Table 4.3 Physio-chemical and microbial quality of beef loin steaks that were subjected to simulated retail display stored for 0, 3, and 6 days from cattle that were fed bermudagrass and native warm season grass

Attribute	Treatment	Day 0	Day 3	Day 6	SEM
pH	CON	5.75^{aX}	5.78^{aX}	5.72^{aX}	
	IND	5.80^{aX}	5.79^{aX}	5.73^{aX}	
	MIX	5.68^{aX}	5.67^{aX}	5.64^{aX}	0.03
Lipid oxidation (mg MDA/kg)	CON	0.15^{bX}	0.10^{bX}	0.56^{aX}	
	IND	0.05^{bX}	0.09^{bX}	0.28^{bY}	
	MIX	0.06^{bX}	0.16^{abY}	0.32^{bY}	0.02
Aerobic Plate Count (log CFU/g)	CON	2.7^{cX}	4.0^{bX}	4.7^{aX}	
	IND	2.5^{cX}	3.9^{bX}	5.0^{aX}	
	MIX	2.6^{cX}	4.1^{bX}	5.0^{aX}	0.04
Cooking loss (%)	CON	23.0^{ab}			
	IND	22.1^{bc}			
	MIX	23.9^{a}			0.2
W.B. Shear force (N)	CON	28.8			
	IND	27.0			
	MIX	30.3			1.0

$^{a-c}$ Means within a row a with the same letter are not different (P>0.05)
$^{X-Z}$ Means within a column within an attribute with the same letter are not different (P>0.05)
CON: Control (Bermudagrass), IND: Indiangrass, MIX: Mix of native warm season grasses
SEM Standard error of means

Table 4.4 The fatty acid profile (triglyceride equivalent %) of beef loin steaks from cattle that were fed bermudagrass and native warm season grass

Triglyceride Equivalent %	**CON**	**IND**	**MIX**	**SEM**
C14:0 Myristic TE(%)	2.9	2.8	2.7	0.1
C15:0 Pentadecanoic TE(%)	0.9	0.8	0.9	0.02
C16:0 Palmitic TE(%)	31.1	31.6	30.3	0.7
C17:0 Heptadecanoic TE(%)	1.5	1.6	1.7	0.03
C18:0 Stearic TE(%)	24.0	22.6	22.0	0.8
C16:1 Palmitoleic TE(%)	2.8	3.0	2.9	0.1
C18:1cis Oleic TE(%)	31.6	32.9	33.9	1.0
C18:2 cis Linoleic TE(%)	3.5	3.5	4.0	0.2
C18:3n9 Linolenic TE(%)	1.9	1.3	1.7	0.1

CON: Control (Bermudagrass), IND: Indiangrass, MIX: Mix of native warm season grasses
SEM Standard error of means

Table 4.5 Consumer acceptability (n=180) of beef loin steaks from cattle that were fed bermudagrass (CON) and native warm season grass

Attribute	CON	IND	MIX
Appearance	6.9	7.0	7.0
Aroma	6.8	6.6	6.6
Flavor	6.6	6.6	6.6
Texture	6.6	6.8	6.6
Overall acceptability	6.6	6.8	6.6

Nine point hedonic scale: 1 = Dislike extremely and 9 = Like extremely
CON: Control (Bermudagrass), IND: Indiangrass, MIX: Mix of native warm season grasses

Table 4.6 Acceptability of beef loin steaks from cattle that were fed bermudagrass and native warm season grass according to different consumer groups

Clusters	Panelists (%)	CON	IND	MIX
1	56.5	7.0[a]	6.9[a]	7.0[a]
2	15.2	4.0[c]	5.0[b]	5.6[a]
3	17.0	7.6[b]	8.3[a]	8.0[a]
4	11.4	6.7[b]	6.5[b]	4.1[b]

[a-c] Means within a row with the same letter are not different (P>0.05)
Nine point hedonic scale: 1 = Dislike extremely and 9 = Like extremely
CON: Control (Bermudagrass), IND: Indiangrass, MIX: Mix of native warm season grasses

Table 4.7 Descriptive sensory attribute and intensity scores (aroma and flavor) of beef steaks from cattle that were fed bermudagrass and native warm season grass and subjected to simulated retail display for 0, 3, and 6 days

Days		**0**			**3**			**6**		
Treatments	CON	IND	MIX	CON	IND	MIX	CON	IND	MIX	SEM
Aroma										
Beef	5.2^{a}	5.3^{a}	5.2^{a}	5.3^{a}	5.0^{a}	5.0^{a}	5.3^{a}	5.0^{a}	5.2^{a}	0.2
Roasted/Browned	3.0^{a}	2.9^{a}	2.7^{ab}	2.8^{ab}	2.5^{ab}	2.7^{ab}	2.7^{ab}	2.4^{b}	2.7^{ab}	0.2
Grassy	1.8^{a}	1.6^{ab}	1.5^{ab}	1.3^{b}	1.1^{c}	1.1^{c}	1.5^{ab}	1.3^{b}	1.2^{bc}	0.18
Livery	2.1^{a}	2.0^{a}	2.1^{a}	1.9^{a}	1.7^{a}	1.8^{a}	2.0^{a}	1.9^{a}	1.9^{a}	0.18
Rancid/Oxidized	0.13^{b}	0.18^{b}	0.12^{b}	0.24^{ab}	0.3^{ab}	0.14^{b}	0.31^{a}	0.37^{a}	0.22^{ab}	0.09
Flavor										
Beef	5.4^{ab}	5.6^{ab}	5.8^{ab}	5.7^{ab}	5.9^{a}	5.8^{ab}	5.4^{ab}	5.3^{ab}	5.0^{b}	0.3
Beef broth	2.6^{ab}	2.7^{ab}	3.1^{a}	3.0^{ab}	3.0^{ab}	2.8^{ab}	2.9^{ab}	2.6^{b}	2.7^{ab}	0.2
Roasted/Browned	2.6^{a}	2.7^{a}	2.7^{a}	2.5^{a}	2.6^{a}	2.2^{a}	2.6^{a}	2.4^{a}	2.4^{a}	0.25
Serumy	2.9^{a}	2.8^{ab}	3.0^{a}	2.8^{ab}	2.8^{ab}	2.7^{ab}	2.3^{b}	2.4^{b}	2.3^{b}	0.24
Rancid	0.16^{c}	0.2^{bc}	0.12^{c}	0.17^{bc}	0.14^{c}	0.22^{bc}	0.4^{a}	0.35^{ab}	0.5^{a}	0.1
Fatty	1.1^{a}	1.3^{a}	1.2^{a}	1.3^{a}	1.3^{a}	1.3^{a}	1.2^{a}	1.0^{a}	1.0^{a}	0.15
Livery	2.3^{a}	2.3^{ab}	2.3^{ab}	2.0^{b}	2.2^{ab}	2.2^{ab}	2.3^{ab}	2.0^{b}	2.4^{a}	0.19
Grassy	1.6^{a}	1.6^{a}	1.5^{a}	1.3^{a}	1.4^{a}	1.4^{a}	1.4^{a}	1.2^{a}	1.5^{a}	0.21
Grainy	0.9^{ab}	1.1^{ab}	1.1^{ab}	0.9^{ab}	1.0^{ab}	1.1^{ab}	1.0^{ab}	1.2^{a}	0.8^{b}	0.15
Nutty	1.3^{a}	1.2^{a}	1.2^{a}	1.1^{a}	1.0^{a}	1.2^{a}	1.2^{a}	1.0^{a}	1.1^{a}	0.18
Metallic	1.2^{ab}	1.3^{ab}	1.5^{a}	0.9^{b}	1.1^{ab}	1.2^{ab}	1.1^{ab}	1.0^{b}	1.4^{a}	0.14
Astringent	1.0^{a}	0.9^{a}	1.0^{a}	0.8^{a}	0.8^{a}	0.8^{a}	0.8^{a}	0.8^{a}	0.8^{a}	0.1

$^{a-c}$ Means within a row with the same letter are not different (P>0.05)

Fifteen point scale used for aroma and flavor where 1 = none and 15 = maximum intensity

CON: Control (Bermudagrass), IND: Indiangrass, MIX: Mix of native warm season grasses

Table 4.8 Descriptive sensory attribute and intensity scores (basic taste and texture) of beef steaks from cattle that were fed bermudagrass and native warm season grass and subjected to simulated retail display for 0, 3, and 6 days

Days	**0**			**3**			**6**			
Treatments	CON	IND	MIX	CON	IND	MIX	CON	IND	MIX	SEM
Basic Taste										
Sweet	0.95^{ab}	1.0^{a}	0.9^{ab}	0.93^{ab}	0.84^{bc}	0.96^{ab}	0.77^{bc}	0.84^{b}	0.7^{c}	0.08
Salty	1.3^{a}	1.4^{a}	1.4^{a}	1.3^{ab}	1.2^{abc}	1.3^{ab}	1.0^{c}	1.1^{bc}	1.2^{abc}	0.09
Bitter	0.5^{a}	0.5^{a}	0.5^{a}	0.5^{a}	0.6^{a}	0.6^{a}	0.5^{a}	0.6^{a}	0.5^{a}	0.08
Sour	0.7^{a}	0.6^{a}	0.6^{a}	0.6^{a}	0.7^{a}	0.7^{a}	0.6^{a}	0.7^{a}	0.6^{a}	0.1
Umami	2.8^{ab}	2.6^{ab}	2.7^{ab}	2.9^{a}	2.7^{ab}	2.8^{ab}	2.4^{b}	2.4^{b}	2.4^{b}	0.18
Texture										
Initial Juiciness	4.8^{b}	5.3^{ab}	5.0^{b}	5.7^{a}	5.0^{b}	5.2^{ab}	5.0^{b}	5.1^{b}	5.0^{b}	0.28
Sustained Juiciness	4.9^{a}	5.1^{a}	5.1^{a}	5.5^{a}	5.1^{a}	5.3^{a}	5.1^{a}	5.0^{a}	5.1^{a}	0.26
Tenderness (first impression)	5.0^{c}	5.5^{ab}	5.2^{b}	5.9^{a}	5.2^{b}	5.6^{ab}	5.3^{abc}	5.2^{bc}	5.1^{bc}	0.26
Tenderness (overall impression)	5.1^{b}	5.5^{ab}	5.2^{ab}	5.7^{a}	5.2^{ab}	5.6^{ab}	5.3^{ab}	5.1^{a}	5.2^{b}	0.24
Amount of connective tissue	5.5^{c}	6.1^{a}	5.9^{ab}	6.2^{a}	6.0^{ab}	6.0^{ab}	5.7^{bc}	5.9^{abc}	5.8^{abc}	0.19

[a-c] Means within a row with the same letter are not different (P>0.05)
Fifteen point scale used for basic taste where 1 = none and 15 = maximum intensity
For texture 8 point scale was used where 1 = extremely dry and 8 = extremely juicy
CON: Control (Bermudagrass), IND: Indiangrass, MIX: Mix of native warm season grasses

4.6 References

Aldai, N., Murray, B. E., Oliván, M., Martínez, A., Troy, D. J., Osoro, K., & Nájera, A. I. (2006). The influence of breed and mh-genotype on carcass conformation, meat physico-chemical characteristics, and the fatty acid profile of muscle from yearling bulls. *Meat Science, 72*(3), 486-495.

AMSA. (2012). Meat color measurement guidelines. American Meat Science Association, Champaign, Illinois, USA.

AMSA. (2012). Research Guidelines for Cookery, Sensory evaluation and instrumental tenderness measurements of fresh meat. *American Meat Science Association in cooperation with National Livestock and Meat Board*, 48.

AOAC. (2000). Official methods of analysis (17th edition), 2nd Vol., Gaithersburg, MD, USA. Association of the Official Analytical Chemists.

AOAC (2007). Official methods of analysis (18th ed.) Arlington, VA, USA. Association of Official Analytical Chemists

Ball, D., & Lacey, G.D. (2007). Southern forages, modern concept for forage crop management. 4th ed., *International Plant Nutrition Inststitute*, Norcross, GA.

Burns, J. (2011). Intake and digestibility among caucasian bluestem, big bluestem, and switchgrass compared with bermudagrass. *Crop Science, 51*(5), 2262-2275.

Calkins, C., & Hodgen, J. (2007). A fresh look at meat flavor. *Meat Science, 77*(1), 63-80.

Cox, R. B., Kerth, C. R., Gentry, J. G., Prevatt, J. W., Braden, K. W., & Jones, W. R. (2006). Determining acceptance of domestic forage-or grain-finished beef by consumers from three southeastern US states. *Journal of Food Science, 71*(7), S542-S546.

Daley, C. A., Abbott, A., Doyle, P. S., Nader, G. A., & Larson, S. (2010). A review of fatty acid profiles and antioxidant content in grass-fed and grain-fed beef. *Nutrition Journal, 9*(1), 1-10.

del Campo, M., Brito, G., de Lima, J. M. S., Martins, D. V., Sañudo, C., Julián, R. S., Hernández, P., & Montossi, F. (2008). Effects of feeding strategies including different proportion of pasture and concentrate, on carcass and meat quality traits in Uruguayan steers. *Meat Science, 80*(3), 753-760.

Descalzo, A., Insani, E., Biolatto, A., Sancho, A., Garcia, P., Pensel, N., & Josifovich, J. (2005). Influence of pasture or grain-based diets supplemented with vitamin E on antioxidant/oxidative balance of Argentine beef. *Meat Science, 70*(1), 35-44.

Duckett, S., Neel, J., Fontenot, J., & Clapham, W. (2009). Effects of winter stocker growth rate and finishing system on: III. Tissue proximate, fatty acid, vitamin, and cholesterol content. *Journal of Animal Science, 87*(9), 2961-2970.

French, P., O'Riordan, E. G., Monahan, F. J., Caffrey, P. J., Mooney, M. T., Troy, D. J., & Moloney, A. P. (2001). The eating quality of meat of steers fed grass and/or concentrates. *Meat Science, 57*(4), 379-386.

French, P., O'Riordan, E. G., Monahan, F. J., Caffrey, P. J., Vidal, M., Mooney, M. T., Troy, D. J., & Moloney, A. P. (2000). Meat quality of steers finished on autumn grass, grass silage or concentrate-based diets. *Meat Science, 56*(2), 173-180.

Johnson, R. J. (2010). Livestock, Dairy, & Poultry Outlook, LDP-M-196, *USDA-ERS* (pp. 4-8). http://usda01.library.cornell.edu/usda/ers/LDP-M//2010s/2010/LDP-M-10-22-2010.pdf.

Kallenbach, R., Crawford, R., Massie, M., Kerley, M., & Bailey, N. (2012). Integrating bermudagrass into tall fescue-based pasture systems for stocker cattle. *Journal of Animal Science, 90*(1), 387-394.

Kerth, C. R., Braden, K. W., Cox, R., Kerth, L. K., & Rankins Jr, D. L. (2007). Carcass, sensory, fat color, and consumer acceptance characteristics of Angus-cross steers finished on ryegrass (Lolium multiflorum) forage or on a high-concentrate diet. *Meat Science, 75*(2), 324-331.

Koohmaraie, M., Kent, M. P., Shackelford, S. D., Veiseth, E., & Wheeler, T. L. (2002). Meat tenderness and muscle growth: Is there any relationship? *Meat Science, 62*(3), 345-352.

Latimori, N., Kloster, A., Garcia, P., Carduza, F., Grigioni, G., & Pensel, N. (2008). Diet and genotype effects on the quality index of beef produced in the Argentine Pampeana region. *Meat Science, 79*(3), 463-469.

Martin, J., & Rogers, R. (2004). Review: Forage-produced beef: Challenges and potential. *The Professional Animal Scientist, 20*(3), 205-210.

Maughan, C., Tansawat, R., Cornforth, D., Ward, R., & Martini, S. (2012). Development of a beef flavor lexicon and its application to compare the flavor profile and consumer acceptance of rib steaks from grass- or grain-fed cattle. *Meat Science, 90*(1), 116-121.

Meilgaard, M., Civille, G. V., Carr, B. T. (2007). *Sensory Evaluation Techniques.* 4th ed. CRC Press, Boca Raton, FL, 275-279.

Neel, J., Fontenot, J., Clapham, W., Duckett, S., Felton, E., Scaglia, G., & Bryan, W. (2007). Effects of winter stocker growth rate and finishing system on: I. Animal performance and carcass characteristics. *Journal of Animal Science, 85*(8), 2012-2018.

Pavan, E., & Duckett, S. K. (2013). Fatty acid composition and interrelationships among eight retail cuts of grass-feed beef. *Meat Science, 93*(3), 371-377.

Peel, D. S. (2011). Market coordination in the beef stocker sector: short and long run implications of higher corn prices. *Southern Agricultural Economics Association annual meeting, Texas* (pp. 6-8). *http://ageconsearch.umn.edu/bitstream/98826/2/Market%2520Coordination%2520in%2520the%2520Beef%2520Stocker%2520Sectorx.pdf*

Pordomingo, A., García, T., & Volpi Lagreca, G. (2012). Effect of feeding treatment during the backgrounding phase of beef production from pasture on: II. Longissimus muscle proximate composition, cholesterol and fatty acids. *Meat Science, 90*(4), 947-955.

Priolo, A., Micol, D., & Agabriel, J. (2001). Effects of grass feeding systems on ruminant meat colour and flavour. A review. *Animal Research, 50*(3), 185-200.

Razminowicz, R. H., Kreuzer, M., & Scheeder, M. R. L. (2006). Quality of retail beef from two grass-based production systems in comparison with conventional beef. *Meat Science, 73*(2), 351-361.

Realini, C. E., Duckett, S. K., Brito, G. W., Dalla Rizza, M., & De Mattos, D. (2004). Effect of pasture vs. concentrate feeding with or without antioxidants on carcass characteristics, fatty acid composition, and quality of Uruguayan beef. *Meat Science, 66*(3), 567-577.

Resconi, V. C., Escudero, A., Beltrán, J. A., Olleta, J. L., Sañudo, C., & Mar Campo, M. d. (2012). Color, lipid oxidation, sensory quality, and aroma compounds of beef steaks displayed under different levels of oxygen in a modified atmosphere package. *Journal of Food Science*, *71*(1)*,* S10-S18.

Scaglia, G., Fontenot, J., Swecker, W., Corl, B., Duckett, S., Boland, H., Smith, R., & Abaye, A. (2012). Performance, carcass, and meat characteristics of beef steers finished on 2 different forages or on a high-concentrate diet. *The Professional Animal Scientist, 28*(2), 194-203.

Schilling, M. W., A. Pham. 2012. Sensory evaluation of muscle foods. Pages 207-224 in Y.H. Hui, editor, Handbook of Meat and Meat Processing, CRC Press, Boca Raton, Florida.

Schilling, M., & Coggins, P. (2007). Utilization of agglomerative hierarchical clustering in the analysis of hedonic scaled consumer acceptability data. *Journal of Sensory Studies, 22*(4), 477-491.

Schmidt, J. (2010). Trends in the production and marketing of grass-fed beef. *Sustainable Agriculture Conference: Connecting Cows, Carbon, & Carrots*. http://old.kansasruralcenter.org/publications/CCCSchmidtOutline.pdf.

Schmidt, T. B., Schilling, M. W., Behrends, J. M., Battula, V., Jackson, V., Sekhon, R. K., & Lawrence, T. E. (2010). Use of cluster analysis and preference mapping to evaluate consumer acceptability of choice and select bovine M. Longissimus Lumborum steaks cooked to various end-point temperatures. *Meat Science, 84*(1), 46-53.

Sitz, B., Calkins, C. R., Feuz, D. M., Umberger, W. J., & Eskridge, K. M. (2005). Consumer sensory acceptance and value of domestic, Canadian, and Australian grass-fed beef steaks. *Journal of Animal Science, 83*(12), 2863-2868.

Thomas, C., Scollan, N., & Moran, D. (2011). A road map for the beef industry to meet the challenge of climate change—A discussion document. *Animal Frontiers, 1*(2), 6-9.

Umberger, W. J. (2003). Country-of-origin labeling of beef products: US consumers' perceptions. *Journal of Food Distribution Research 34*(3), 103-116.

Umberger, W. J., Boxall, P. C., & Lacy, R. C. (2009). Role of credence and health information in determining US consumers' willingness-to-pay for grass-finished beef. *Australian Journal of Agricultural and Resource Economics, 53*(4), 603-623.

Wyrwisz, J., Półtorak, A., Zalewska, M., Zaremba, R., & Wierzbicka, A. (2012). Analysis of relationship between basic composition, pH, and physical properties of selected bovine muscles. *Bulletin of the Veterinary Institute in Pulawy, 56*(3), 403-409.

Yang, A., Lanari, M. C., Brewster, M., & Tume, R. K. (2002). Lipid stability and meat colour of beef from pasture- and grain-fed cattle with or without vitamin E supplement. *Meat Science, 60*(1), 41-50.

Yin, M. C., Faustman, C., Riesen, J. W., & Williams, S. N. (1993). α-Tocopherol and ascorbate delay oxymyoglobin and phospholipid oxidation in vitro. *Journal of Food Science, 58*, 1273-1276.