RELATIONSHIPS BETWEEN NUTRIENT COMPONENTS OF LONGISSIMUS MUSCLE AND BEEF PALATABILITY TRAITS AND INFLUENCE OF FINISHING DIET ON BEEF QUALITY

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TABLE OF CONTENTS

Chapter Page

LIST OF TABLES

Table Page

LIST OF FIGURES

Figure Page

CHAPTER I

INTRODUCTION

Beef producers strive to produce a high quality product that meets consumer needs in a cost-effective manner. Ideally, they would like to select cattle with a higher propensity to marble, while some consumers favor a lower concentration of saturated fatty acids due to their negative effect on human health. The most abundant fatty acids in bovine fat are oleic (C18:1), palmitic (C16:0), and stearic (C18:0). Myristic (C14:0), palmitoleic (C16:1), linoleic (C18:2), and linolenic (C18:3) fatty acids are also found, but to a much lesser extent. Oleic is by far the most abundant fatty acid, comprising 40-50% of all fatty acids. According to USDA (2009), C18:1 accounts for 44.8% of total fatty acids of beef top loin. Palmitic acid ranges between 27-28%, and stearic typically averages 15% of the total concentration of fatty acids in beef top loin. The remaining fatty acids are present anywhere from 1-4%, with C16:1 representing 4%, C14:0 at 3.5%, C18:2 at 3.3%, and C18:3 accounting for 0.7% of the total proportion of fatty acids in beef top loin (USDA, 2009). Beef could be viewed more favorably from a human health standpoint if strategies could be applied to reduce saturated fatty acids while increasing beneficial polyunsaturated fatty acids (PUFA), especially omega-3 PUFA and conjugated linoleic acid. Although fatty acid profiles can be altered through the diet to increase the concentration of PUFA (Realini et al., 2004; Faucitano et al., 2008), fatty acid

composition varies between (Yang et al., 1999; Laborde et al., 2001; and Pitchford et al., 2002) and within breeds (Oka et al., 2002). Since natural genomic variation exists, development of genetic tools such as DNA markers would allow beef producers to select cattle to enhance the nutritional value of beef. The overall objective of this joint venture with Iowa State University and Pfizer was to evaluate natural genomic variation.

To achieve this goal, live animal and carcass data were collected from three related populations of Angus cattle in different geographical locations across the country. Longissimus muscle samples were obtained to perform tests assessing beef palatability traits and the nutrient composition of the meat. Animals were genotyped to evaluate the extent to which genetics control phenotypic variation of the nutritional composition of meat. The influence of nutrient components on beef palatability was evaluated to ensure tenderness, flavor, and juiciness were not compromised when selecting cattle with enhanced nutritional composition.

Beef is well known for its superior eating experience over other protein sources; however, red meat is often classified as a fatty protein source with certain health risks associated with its consumption. Consumers demand safe, flavorful, and healthy meat products. Beef is already an excellent source of protein, vitamins, and minerals, but if strategies could be applied to further enhance the nutritional value of beef, this could increase consumer demand for beef, keeping the beef industry competitive with other animal protein sources as the nation's choice for healthy meat products.

CHAPTER II

REVIEW OF LITERATURE

Effect of fat and lipid content on beef palatability

Fat content has been shown to be associated with palatability. Generally, there is a small, positive correlation between fat content (degree of marbling) and tenderness, juiciness, and beef flavor intensity, and a small inverse relationship between marbling and Warner-Bratzler shear (WBS) force values. Smith et al. (1984) selected 1,005 beef carcasses of varying maturity and degree of marbling and collected strip loins for trained sensory analysis and WBS analysis. Steaks from carcasses with higher marbling scores had lower ($P < 0.05$) shear force values and higher ($P < 0.05$) sensory panel ratings than steaks with lower marbling scores. Higher marbling scores were associated with a more desirable mean flavor rating in 31.7% of comparisons with steaks with lower marbling scores. In similar comparisons, percentages were 39.3 for juiciness, 18.8 for amount of connective tissue, 35.7 for tenderness, 35.3 for overall palatability, and 27.7 for shear force value. Results indicated carcasses with higher marbling scores will yield steaks that are more flavorful, juicy, tender, and palatable one-third of the time, explaining approximately 33% of the variation in overall palatability in steaks from the loin (Smith et al., 1984).

Wheeler et al. (1994) evaluated the effect of marbling on palatability in *Bos*

taurus and *Bos indicus* cattle. Meat was collected from 1,667 carcasses for WBS and trained sensory analyses. Meat from both *Bos taurus* and *Bos indicus* cattle decreased ($P < 0.05$) in shear force as marbling increased from traces to small; however, there was no difference ($P > 0.05$) in shear force values for steaks within the USDA Choice grade (small, modest, and moderate). Meat with small, modest, and moderate marbling from *Bos taurus* cattle and meat with slight and small marbling from *Bos indicus* cattle were rated higher ($P < 0.05$) in overall tenderness by panelists than meat with lower marbling scores. Steaks with modest and moderate marbling from *Bos taurus* cattle were rated more juicy ($P < 0.05$) than steaks with traces or slight marbling, but juiciness was not different ($P > 0.05$) between marbling scores in *Bos indicus* cattle. Panelists found no difference ($P > 0.05$) in beef flavor intensity between marbling scores in *Bos taurus* and *Bos indicus* cattle. Although there was a small, positive relationship between marbling score and beef palatability, marbling score only accounted for about 5% of the variation in palatability traits (Wheeler et al., 1994).

Lorenzen et al. (2003) selected Top Choice (modest or moderate marbling), Low Choice, High Select, and Low Select carcasses to compare trained sensory panel ratings and WBS values. Panelists rated Top Choice top loin steaks higher ($P < 0.05$) in muscle fiber tenderness than both levels of Select steaks. No differences ($P > 0.05$) were detected by panelists in connective tissue amount across USDA quality grade. Panelists rated Top Choice top loin steaks juicier ($P < 0.05$) than all other grades. Top Choice steaks were rated higher ($P < 0.05$) for cooked beef flavor intensity than Low Choice steaks, and Low Choice steaks had more intense ($P < 0.05$) beef flavor than Select steaks.

When steaks were cooked above 65º C, Choice steaks had lower ($P < 0.05$) WBS values than Select steaks (Lorenzen et al., 2003).

Not only the amount, but the composition of fat can affect palatability in beef. Kazala et al. (1999) investigated the relationship between fatty acid profiles and marbling in beef cattle. Overall, marbling score was negatively ($P < 0.001$) correlated with total lipid and triacylglycerol content of the longissimus muscle (LM). However, this negative correlation was due to the inverse scale for the marbling score used in the Canadian grading system (1 = very abundant marbling; 10 = devoid). Generally, the concentrations of 14:0, 16:0, and 16:1 increased with lipid content, while the concentrations of 18:0, 18:1, and 18:2 were reduced. As marbling score increased (actual amount of marbling decreased), 14:0 tended ($P < 0.10$) to decrease, while the concentration of 18:0 ($P < 0.05$) and 18:2 ($P < 0.001$) increased (Kazala et al., 1999).

Although marbling plays a significant role in determining beef quality, perhaps the greatest significance of fatty acids on meat quality is their effect on palatability, especially on beef flavor. Dryden and Marchello (1970) evaluated the impact of fatty acids on palatability of three beef muscles – semimembranosus (SM), triceps brachii (TB), and longissimus dorsi (LD). Very few significant and no consistently strong correlations existed between individual fatty acids and sensory panel traits. The concentration of 18:1 was positively correlated ($P < 0.05$) with flavor in LD. In TB, 17:0 was negatively correlated ($P < 0.05$) and iso18:0 was positively correlated ($P < 0.01$) with flavor. Warner-Bratzler shear force values were negatively correlated ($P < 0.05$) with 17:0 in TB, SM, and all muscles pooled, but not in LD (Dryden and Marchello, 1970).

Westerling and Hedrick (1979) evaluated the association between fatty acids and sensory characteristics. Flavor was negatively correlated with 16:0, 18:0, 18:2, and total SFA ($P < 0.01$), but was positively correlated ($P < 0.01$) with the concentration of 18:1 and total UFA in the intramuscular fat of the LD. There were no significant correlations between specific fatty acids and juiciness or tenderness ratings (Westerling and Hedrick, 1979).

Melton et al. (1982a) conducted consumer sensory panels to evaluate differences in flavor of ground beef from steers of five different dietary regimes. Significant correlations were observed between flavor score and particular fatty acids. Myristoleic acid (14:1) ($P < 0.01$), 18:0 ($P < 0.01$), and 18:3 ($P < 0.001$) of the neutral fraction, as well as 18:0 ($P < 0.05$), 18:3 ($P < 0.001$), and 20:4 of the polar fraction were negatively correlated with flavor scores. As concentrations of these fatty acids increased, lower flavor ratings were observed. The only significant ($P < 0.01$) positive correlation was observed for 18:1 of the neutral fraction. A higher concentration of this fatty acid was associated with more desirable flavor (Melton et al., 1982a).

In another study conducted by Melton et al. (1982b), simple correlations were generated between specific fatty acids and several flavor descriptors of ground beef. Three monounsaturated fatty acids (16:1, 17:1, and 18:1) were negatively correlated with fishy flavor ($P < 0.05$). Simple correlation coefficients were - 0.32, - 0.37, and - 0.38 for 16:1, 17:1, and 18:1, respectively. However, some fatty acids were positively correlated to fishy flavor with coefficients of 0.36, 0.57, 0.41, 0.26, and 0.30 for 15:0, 18:0, 18:3, 19:1, and 20:4, respectively ($P < 0.05$). Only 14:1, 16:1, and 18:0 had significant ($P < 0.05$) correlation coefficients for liver flavor at 0.27, 0.32, and - 0.33, respectively. The

monounsaturated fatty acids, 16:1, 17:1, and 18:1 were positively correlated to cooked beef flavor with coefficients of 0.41, 0.26, and 0.30, respectively ($P < 0.05$). Conversely, 15:0, 18:0, 18:3, 20:4, and 20:1 were negatively correlated to cooked beef flavor with coefficients of - 0.38, - 0.51, - 0.39, - 0.34, and - 0.30, respectively ($P < 0.05$).

Mandell et al. (1998) reported sensory attributes of ribeye roasts and ground beef were typically unchanged by diet, which compared grain- vs. forage-feeding. However, they did note a slight reduction in beef flavor, as well as more off-flavors in forage-fed vs. grain-fed steers. Forage-fed beef had a higher ($P < 0.01$) concentration of 18:3 and a lower ($P < 0.10$) concentration of 18:1, which may have influenced the differences in flavor (Mandell et al., 1998).

Realini et al. (2004) compared the effect of forage- vs. concentrate-feeding of Hereford steers on fatty acid composition. Concentrate-fed steers were harvested after 100 d on feed, and forage-fed steers were harvested after 130 d. After harvest, the ribeye roll (IMPS 112) was collected and fabricated into steaks. Concentrate-fed steers had significantly ($P < 0.01$) higher concentrations of 14:0, 16:0, and 18:1, and lower ($P < 0.01$) concentrations of 18:0, 18:2, 18:3, 20:4, 20:5, and 22:5 when compared to forage-fed steers. Pasture-fed steers had higher ($P < 0.01$) concentrations of total conjugated linoleic acid (CLA) and CLA isomer c9t11 than concentrate-fed steers. Initial tenderness was similar ($P > 0.05$) between dietary regimes. However, pasture-fed steers produced steaks with lower ($P < 0.05$) WBS values at 7 and 14 d postmortem, showing more potential for postmortem tenderization through aging. It is, however, unclear whether the difference in fatty acid composition is responsible for the difference in tenderness in aged steaks (Realini et al., 2004).

Faucitano et al. (2008) evaluated five dietary/management regimes and their influence on fatty acid composition. Treatments involved combinations of forage-and concentrate-feeding with or without growth promotants. During the growing phase (d 0 to d 98) Angus cross steers were assigned to one of five management regimes, including: 1) grass silage (GS), 2) grass silage with growth promotants (GS/GP), 3) grass silage plus 4% soybean meal (GS + LCON), 4) grass silage plus 8% SBM (GS + HCON), or 5) grass silage plus 8% SBM plus growth promotants. In the finishing phase (d 99 to harvest), the five management regimes were kept in place; however, 4% SBM was replaced with 40% rolled barley for LCON, and 8% SBM was replaced with 70% rolled barley for HCON. Animals allotted to the GS/GP and GS/GP + HCON treatments were implanted with Revalor G (40 mg of trenbolone acetate + 8 mg of estradiol; Hoechst-Roussel Agri- Vet, Somerville, NJ) and were reimplanted after 70 d with Revalor S (120 mg of trenbolone acetate + 24 mg of estradiol; Hoechst-Roussel Agri-Vet). Growth promotants increased ($P < 0.05$) the percentages of 18:0, 20:0, trans isomers of 18:1, and 18:2c-9, t-11. Steers fed exclusively forage had increased concentrations of 18:2c9c11 ($P < 0.01$) and 18:3c9c12c15 ($P < 0.05$) and decreased concentrations of 18:1t10 ($P < 0.05$) and the ratio of n-6:n-3 ($P < 0.05$). In terms of palatability, grain feeding increased intramuscular fat content ($P < 0.05$); however, diet did not affect sensory panelists' ratings of flavor or juiciness ($P > 0.05$). Warner-Bratzler shear force values were similar ($P > 0.05$) across diets; however, in contrast to most studies, panelists rated forage-finished beef more tender than beef from cattle fed high-concentrate diets (Faucitano et al., 2008).

Jenschke et al. (2007) conducted sensory analysis, proximate analysis, heme iron, mineral content, and fatty acid analysis on beef knuckles to determine factors

contributing to livery off-flavor. A regression equation was derived that accounted for 46% of the variation in livery off-flavor; sodium, 16:1, cis 18:1n-7, 20:2n-6, and 20:3n-6 were included in the equation. As the concentration of 20:2n-6 increases, livery off-flavor would be expected to increase. However, all other significant factors had a negative correlation with livery off-flavor (Jenschke et al., 2007).

Generally, there is a small, positive correlation between fat content (degree of marbling) and tenderness, juiciness, and beef flavor intensity, and a small inverse relationship between marbling and Warner-Bratzler shear (WBS) force values. In addition, the composition of lipids can influence beef palatability. The concentrations of 14:0, 16:0, and 16:1 have been shown to increase with lipid content, while the concentrations of 18:0, 18:1, and 18:2 decline. Several studies have evaluated the association between fatty acid composition and sensory characteristics, particularly beef flavor, producing variable results. However, researchers consistently found a positive correlation between beef flavor intensity and the concentration of oleic acid.

Relationship between fat content, lipid oxidation, and beef flavor

The susceptibility of a fatty acid to oxidize is related primarily to the degree of unsaturation; however, the fatty acid composition of the lipid, the presence and activity and pro- and antioxidants, oxygen level, and storage conditions (temperature, light intensity/exposure, moisture content, etc.) will all affect the rate of autoxidation of meat products (Belitz et al., 2004). Although it is desirable to increase PUFA in meat for its benefit to human health, off-flavors are more likely to develop during cooking when PUFA levels become too high (Elmore et al., 2002).

Smith and Alfawaz (1995) generated correlation coefficients between sensory scores and thiobarbituric acid reactive substances (TBARS) values of cooked ground beef. They found sensory scores for cooked lean beef flavor were negatively correlated (r^2 = - 0.93) to TBARS values and positively correlated to cardboard (r^2 = 0.79), painty (r^2 = 0.70), and bitter (r^2 = 0.79) flavors ($P < 0.0001$). Cardboard, painty, and bitter flavors can all be used to describe oxidative rancidity (Smith and Alfawaz, 1995).

Campo et al. (2006) performed TBARS and sensory analyses on steaks to evaluate flavor perception of oxidation in beef from cattle exposed to a wide variety of potential oxidation through differences in the PUFA composition. There was a significant ($P < 0.001$) positive correlation (r^2 = 0.84) between TBARS and rancid flavor, indicating TBARS were a good predictor for the perception of oxidation. Moreover, TBARS were also significantly correlated ($P < 0.001$) with beef (r = - 0.80), metallic (r = - 0.36), and livery flavors (r = - 0.60), as well as overall liking (r = - 0.84). Campo et al. (2006) also determined a TBARS value of approximately 2 (expressed as mg of malonaldehyde per kg of lean muscle) could be set as a threshold for acceptability of oxidized beef.

The products of fatty acid oxidation generally produce off-flavors that can be classified as rancid. The measurement of TBARS is one lab assay that can be used to quantify the extent of lipid oxidation in meat products. Studies have shown a strong positive correlation between TBARS values and sensory ratings of rancid flavor intensity. In addition, TBARS are negatively correlated with beef, metallic, and livery flavors.

Beef flavor relationship with iron content

Meisinger et al. (2006) examined the relationship of pH and heme-iron to off-flavor in muscles from the chuck and round, including the rectus femoris (REC), vastus medialis (VAM), vastus lateralis (VAL), teres major (TER), infraspinatus (INF), and triceps brachii (TRI). Heme iron and pH could partially explain livery flavor in the REC, VAM, and VAL (R^2 = 0.45 to 0.55; $P < 0.05$), but were unrelated to metallic, oxidized, or rancid flavors in any of the muscles in the study (Meisinger et al., 2006).

Yancey et al. (2006) investigated several factors, including total iron content, which may affect the livery off-flavor development in beef. They obtained steaks from the infraspinatus (IN), gluteus medius (GM), and psoas major (PM) for their analysis. The IN had higher ($P < 0.05$) iron content when compared to the GM or PM; however, beef flavor identification by trained sensory panelists was not influenced by total iron content in the IN. Liver flavor intensity increased ($P < 0.05$) and beef flavor intensity declined ($P < 0.05$) in the GM as total iron increased. In the PM, liver-like flavor decreased ($P < 0.05$) as total iron increased, but beef flavor detection was not changed ($P > 0.05$) by iron content. Yancey et al. (2006) demonstrated there were relationships between liver flavor development in beef and total iron content, among other factors, but those relationships are relatively low.

The relationship between total iron content and beef flavor still seems unclear based on these results. Iron content varies between different muscles, and there is not always a consistent relationship between iron content and beef, livery, or metallic flavors. Relationships that do exist are generally very low.

Relationship between Warner-Bratzler shear force and sensory ratings of tenderness

Since tenderness plays such a large role in consumer satisfaction, it is extremely important to understand the relationship between alternative measures of tenderness. Shackelford et al. (1991) used regression analysis of WBS values and trained sensory panel overall tenderness ratings of strip steaks to determine threshold WBS values. Threshold WBS values for retail and foodservice strip steaks were 4.6 and 3.9 kg, respectively. In the retail sector, a WBS value of 4.6 kg was 88.6% accurate at predicting whether or not a consumer would rate a steak as less than "slightly tender" when these values were evaluated against the beef used in the National Consumer Retail Beef Study (Shackelford et al., 1991).

Shackelford et al. (1995) found a strong relationship ($r^2 = 0.73$) between peak load and overall tenderness for the longissimus dorsi when they analyzed the relationship between instrumental tenderness and trained sensory panel tenderness scores. Furthermore, overall tenderness was significantly correlated with juiciness ($r = 0.51$; $P < 0.05$) and amount of connective tissue ($r = 0.76$; $P < 0.001$) in the longissimus muscle (Shackelford et al., 1995).

In a study by Miller et al. (1995), consumers in the home began to rate beef steaks as tough rather than tender between WBS values of 5.0 kg and 4.6 kg, while consumers in a restaurant setting were slightly more tolerable of tough meat with the transition in WBS values occurring between 5.2 kg and 4.3 kg. Furthermore, results indicated consumer acceptability level of a beef steak is breached when shear values are $\geq$ 4.3 kg (Miller et al., 1995). In a nationwide study by Miller et al. (2001), consumers began to perceive beef steaks as tough rather than tender between WBS values of 4.3 kg and 4.9 kg based on $\geq$ 86% consumer acceptability. Furthermore, results indicate WBS

tenderness values of < 3.0, 3.4, 4.0, 4.3, and 4.9 kg would produce 100, 99, 94, 86, and 25% consumer satisfaction for beef tenderness (Miller et al., 2001).

There is a strong relationship between WBS values and trained sensory panel tenderness scores. Overall tenderness scores are also correlated with juiciness and connective tissue amount. As we work to improve beef tenderness, this should also have a positive impact on other beef palatability traits.

It is important to understand the relationship between fat content, fatty acid composition, and palatability to ensure tenderness, flavor, and juiciness are not compromised when selecting cattle with enhanced nutritional composition. Most fatty acids have little or variable effect on beef palatability, but oleic acid (18:1) is consistently correlated with beef flavor in a positive manner. Therefore, we must assess the influence of certain nutrient components (fatty acids, minerals, etc.) on tenderness and sensory characteristics as well as lipid oxidation to fully understand how they affect product quality.

Influence of diet on beef palatability, lipid oxidation, and color stability

Fatty acid profiles in intramuscular fat can be altered and enhanced by incorporating grass in the diet (French et al., 2000; Realini et al., 2004). Higher grass intake can decrease the concentration of SFA, while increasing the ratio of polyunsaturated fatty acids to saturated fatty acids (PUFA:SFA) and the concentration of beneficial conjugated linoleic acid.

While forage-based finishing systems can enhance the nutritional value of beef, their effect on palatability traits, lipid oxidation, and color stability remains mixed. In a study comparing shelf-life and palatability of forage and concentrate diets, Schroeder et

al. (1980) reported panelists thought steers on a high energy diet produced steaks that were juicier, more desirable in flavor, and more tender. In addition, grain-finishing reduced WBS values. In contrast, French et al. (2001) found no differences in tenderness or sensory traits between diets of varying levels of grass and concentrates. Faucitano et al. (2008) actually reported decreased sensory panel tenderness scores for grain-fed cattle compared to forage-fed cattle, while no differences were observed in WBS values between diets. When comparing the effect of forage- vs. concentrate-feeding of Hereford steers, Realini et al. (2004) examined tenderness, lipid oxidation, and color stability. Initial tenderness was similar between dietary regimes. However, pasture-fed steers produced steaks with lower WBS values at 7 and 14 d postmortem.

O'Sullivan et al. (2003) demonstrated that lipid oxidation was higher in concentrate-fed animals compared to animals with various levels of forage inclusion in their diet. This difference was observed initially and throughout retail display. Similarly, Realini et al. (2004) reported steaks from pasture-fed animals had lower initial TBARS values than steaks from concentrate-fed animals, with this advantage being maintained throughout retail display. In contrast, Yang et al. (2002) found that pasture feeding increased lipid oxidation of aged beef compared to grain-fed beef supplemented with vitamin E. Increasing the PUFA content due to forage feeding can increase the susceptibility to lipid oxidation; however, the vitamin E antioxidant found in forage-based diets can offset the proxidative properties of PUFA, thus reducing lipid oxidation.

In terms of color stability, Schroeder et al. (1980) found steaks from concentrate-fed steers had brighter initial muscle color and did not discolor as rapidly as steaks from forage-fed steers. Yang et al. (2002) reported lower a* values in meat from pasture-fed

cattle compared to grain-fed beef with or without vitamin E supplementation. Realini et al. (2004) showed pasture-fed carcasses had lower L* values, indicating darker longissimus lean color when compared to concentrate-fed carcasses, and pasture-fed steers yielded carcasses with subcutaneous fat that had higher b* values, indicating more yellowness than concentrate-fed steers. However, other studies (French et al., 2001 and O'Sullivan et al., 2003) have not found significant differences in color due to diet.

It seems for every study reporting the benefits of forage feeding, another exists that fails to find any differences with concentrate feeding, making it difficult to assess the real value of alternative beef finishing systems. In addition, these studies either compare diets on a similar compositional end point or similar time on feed. Feeding to similar end point often results in forage-fed cattle that are much older than their grain-fed counterparts, confounding results for palatability, especially beef tenderness. Limiting the time on feed of forage-fed cattle will limit fat deposition, both externally and internally. Again, this could potentially confound results, making it difficult to interpret results and compare studies of this nature.

CHAPTER III

ESTIMATION OF PHENOTYPIC CORRELATIONS BETWEEN NUTRIENT COMPONENTS OF LONGISSIMUS MUSCLE AND BEEF PALATABILITY TRAITS IN RELATED CATTLE IN DIFFERENT GEOGRAPHIC LOCATIONS

ABSTRACT

The objective of the study was to determine the influence of beef longissimus muscle nutrient components on beef palatability traits. Cattle from two related herds in California (n = 382) and Iowa (n = 194) were utilized. Longissimus muscle samples were obtained and fabricated into steaks for trained sensory panel, Warner-Bratzler Shear force (WBS), thiobarbituric acid reactive substances (TBARS), fatty acid and mineral composition analysis. Pearson phenotypic correlations were obtained through the correlation procedure of SAS. Specific mineral concentrations did not demonstrate strong correlations with WBS, sensory traits, or TBARS, and significant correlations were not consistent between the two cattle populations. Linolenic acid (C18:3n-3) was the only fatty acid significantly correlated ($P < 0.05$) with WBS in the California samples, but C18:1, C18:2, C18:3n-3, C18:3n-6, and MUFA were significantly correlated ($P < 0.05$) with WBS in the Iowa samples. No significant correlations ($P > 0.05$) existed between initial and sustained juiciness and any of the major beef fatty acids in the California cattle; however, there were weak correlations ($P < 0.05$) with C16:0, C18:0,

C18:1, C18:2, SFA, MUFA, and the sum of n-6 fatty acids in Iowa samples. Specific fatty acids that demonstrated significant correlations with sensory tenderness ratings were generally weak and inconsistent between the two populations. Correlations were rather weak, but beef flavor was positively correlated ($P < 0.05$) with C14:0, C16:0, C18:1, and MUFA in both populations. Painty/fishy flavor was negatively correlated ($P < 0.05$) with C18:2, PUFA, and the sum of n-6 fatty acids in California samples, but was positively correlated ($P < 0.05$) with the same traits in the Iowa samples. There were no consistent relationships between lipid composition and livery/metallic flavor between the two populations. In general, specific fatty acids and minerals did not demonstrate strong correlations with beef palatability traits, and relationships that did exist were generally low.

INTRODUCTION

Today's typical consumers are health conscious individuals that are becoming increasingly aware of the amount and type of fats they consume. Red meat is often perceived as a fatty protein source with certain health risks associated with its consumption. Beef could be viewed more favorably from a human health standpoint if strategies could be applied to reduce saturated fatty acid (SFA) content while increasing the concentration of beneficial polyunsaturated fatty acids (PUFAs), especially omega-3 PUFAs, and conjugated linoleic acid. Additionally, fats are not the only nutrients that impact the nutritional value of beef. Minerals, such as iron are required in the human diet, and beef is an excellent source of iron, yet the consistency of iron content in beef products is highly variable.

Beef producers strive to produce a high quality product that meets consumer needs in a cost-effective manner. Fatty acid profiles can be altered through the diet to increase the concentration of PUFAs (Realini et al., 2004; Faucitano et al., 2008). However, identification of genetic markers that would allow producers to select beef for optimum nutritional values, with respect to fatty acids, minerals, and vitamins, without sacrificing performance or product quality could ultimately increase value and consumer satisfaction of beef.

Ideally, producers would like to select cattle with a higher propensity to marble, while some consumers favor lower levels of SFA due to their negative effect on human health. However, researchers must first understand the relationship between fat content, fatty acid composition, and palatability to ensure tenderness, flavor, and juiciness are not compromised when selecting for cattle with enhanced nutritional composition. Most fatty acids have little or variable effect on beef palatability, but oleic acid (18:1) is consistently correlated with beef flavor in a positive manner (Dryden and Marchello, 1970; Westerling and Hedrick, 1979; and Melton et al., 1982a). Therefore, the goal of the present study was to assess the influence of certain fatty acids and minerals of beef longissimus on tenderness and sensory characteristics as well as lipid oxidation to understand how they affect product quality.

MATERIALS AND METHODS

The Oklahoma State University Institutional Review Board (IRB) approved the experimental protocol used in the present study (See Appendix A).

Animal Resources

Two separate but related beef cattle resources were utilized in this study. The Iowa State University Research Herd has been selected for increased intramuscular fat (IMF) since it began in 1996. Approximately 200 head were harvested from each calf crop, and data were collected on a portion of these from 2007 through 2008. A related herd exists in California that has been selected for increased IMF. In 2008, approximately 400 head were harvested by Harris Ranch for use in this study.

Harvest and Data Collection

Cattle were harvested at commercial harvest facilities in Iowa and California. Trained personnel obtained carcass measurements, including hot carcass weight (HCW), ribeye area (REA), marbling score (MS), percentage kidney, pelvic, and heart fat (KPH), fat thickness (FAT), USDA yield grade, and USDA quality grade. The scale used for data entry of MS was 3.0 = traces, 4.0 = slight, 5.0 = small, 6.0 = modest, 7.0 = moderate, 8.0 = slightly abundant, and 9.0 = moderately abundant.

Sample Collection and Preparation

Sample collection was unique in each plant. In Iowa, two rib sections were obtained from each carcass. Samples were collected, packaged, and transported to the Iowa State University Meat Laboratory, Ames. Starting from the 12^{th} - 13^{th} rib interface, two 2.54 cm thick steaks were removed for WBS and sensory analysis. Two 1.27 cm steaks were removed next for healthfulness and thiobarbituric acid reactive substances (TBARS). External fat and connective tissue were removed from the healthfulness and TBARS steaks. All steaks were vacuum packaged, aged for 14 d from the harvest date and then frozen. After samples were frozen, WBS, sensory, and TBARS steaks were

transported to the Oklahoma State University (OSU) Food and Agricultural Products Center (FAPC), Stillwater.

In California, one rib section was removed from each carcass. Samples were collected, packaged, and transported to the OSU FAPC. The initial group from California was shipped fresh. Starting from the 12^{th} - 13^{th} rib interface, a face steak was removed and trimmed for TBARS. Two 2.54 cm steaks were then removed for WBS and sensory analysis, followed by a 1.27 cm steak for healthfulness. All steaks were vacuum packaged, aged for 14 d from the harvest date at 2ºC, and then frozen at -20ºC for subsequent analysis. Due to shipping restrictions of the second group, rib sections were frozen after 14 d postmortem at the plant in California and shipped to OSU FAPC frozen. The same procedure was used to obtain the four steaks; however, rib sections were sliced in a frozen state. Steaks were vacuum packaged and placed in a freezer at -20ºC for subsequent analysis. Healthfulness steaks were shipped frozen to the Iowa State University Meat Laboratory for analysis.

Warner Bratzler Shear Force (WBS)

The frozen steaks were allowed to temper at 4ºC for 24 h prior to cooking. Steaks were broiled in an impingement oven (XLT Impinger, Model 3240-TS, BOFI Inc., Wichita, KS or Lincoln Impinger, Model 1132-000-A, Lincoln Foodservice Products, Fort Wayne, IN) at 200ºC to an internal temperature of 68ºC. An Atkins AccuTuff 340 thermometer (Atkins Temtec, Gainesville, FL) was used to measure the temperature of steaks as they exited the oven. If they had not yet reached 68ºC, they were returned to the conveyor until they reached 68ºC. After cooking, steaks were cooled at 4ºC for 18 to 24 h. Six cores, 1.27 cm in diameter, were removed parallel to muscle fiber orientation

and sheared once, using a Warner-Bratzler head attached to an Instron Universal Testing Machine (Model 4502, Instron Corporation, Canton, MS). The Warner-Bratzler head moved at a crosshead speed of 200 mm/min. Peak load (kg) of each core was recorded by an IBM PS2 (Model 55 SX) using software provided by the Instron Corporation. Mean peak load (kg) was analyzed for each sample.

Sensory Analysis

Steaks were assigned a randomized number for sensory sessions. Steaks were allowed to temper at 4ºC for 24 h prior to cooking, cooked to 68°C as described above for WBS, sliced into approximately 2.54-cm × 1.27-cm × 1.27-cm samples, and served warm to panelists.

Sensory attributes were evaluated by an eight member, trained panel consisting of Oklahoma State University personnel. Panelists were trained for tenderness, juiciness, and three specific flavor attributes (Cross et al., 1978). Sensory sessions were conducted once or twice a day and contained 12 samples each. Samples were evaluated using a standard ballot from the American Meat Science Association (AMSA, 1995). Panelists evaluated samples in duplicate for initial (IJ) and sustained juiciness (SJ), initial (IT) and overall tenderness (OT), and amount of connective tissue (CT) using an 8-point scale. Panelists evaluated cooked beef flavor (BF), painty/fishy flavor (PFF), and livery/metallic flavor (LMF) intensity using a 3-point scale. For juiciness, the scale was 1 = extremely dry and 8 = extremely juicy. The scale used for initial and overall tenderness was 1 = extremely tough and 8 = extremely tender. The scale used for connective tissue was 1 = abundant and 8 = none. The scale used for beef flavor and off-flavor intensity was 1 = not detectable, 2 = slightly detectable, and 3 = strong.

During sessions, panelists were randomly seated in individual booths in a temperature and light controlled room. While being served, the panelists were under red filtered lights as suggested by the American Meat Science Association (AMSA, 1995). The 12 samples were served in a randomized order according to panelist. The panelists were provided distilled, deionized water and unsalted crackers to cleanse their palate.

Thiobarbituric Acid Reactive Substances (TBARS)

Lipid oxidation was evaluated by TBARS using the modified method of Buege and Aust (1978). A 10 g sample was placed in a blender (model 51BL31, Waring Products, Inc., Torrington, CT) and homogenized with 30 ml of cold deionized water. The mixture was transferred to a disposable tube and centrifuged for 10 min at 3000 rpm. Two ml of supernatant was pulled from the tube and placed in disposable glass tube with 4 ml of thiobarbituric acid/trichloroacetic acid (TBA/TCA) and 100 μL of butylated hydroxyanisol (BHA). Tubes were vortexed and then incubated in a boiling water bath for 15 min, followed by 10 min in a cold water bath. After cooling, samples were centrifuged for 10 min at 3000 rpm. The absorbance was read at 531 nm. A standard curve was generated for each day of analysis using 1,1,3,3-tetra-ethoxypropane (TEP). Lipid oxidation was measured in duplicate for each steak, and the average absorbance reading was used for each sample. Results were expressed as mg of malonaldehyde per kg of sample.

Nutrient Phenotype Collection

Healthfulness samples were frozen and ground before fatty acid and mineral assays. An approximately 4 g sample was dried at 105ºC for 18 to 20 h (AOAC, 2000). Longissimus muscle samples were prepared for mineral analyses using microwave

digestion (MDS-2000, CEM, Matthews, NC). For longissimus muscle (LM) digestion, 0.35 - 0.40 g of dry material was added to 5 mL concentrated HNO_3 and 2 mL 30%H_2O_2. Vessels were then placed in the microwave digestor, and power was applied for 45 min. Digested samples were transferred to volumetric flasks and diluted with deionized water. Samples were analyzed for their mineral content using inductively coupled plasma-optical emission spectroscopy (SPECTRO Analytical Instruments, Fitchburg, MA) as outlined by AOAC (2000). Concentrations of phosphorus, potassium, sodium, calcium, copper, iron, magnesium, manganese, and zinc were calculated. To calculate the sample mineral concentration (ppm), the measured mineral concentration (ppm) was multiplied by the number of dilutions and divided by the sample weight (g). Phosphorus and potassium were diluted 250 times, and all other minerals were diluted 25 times. A standard was used for calibration between different groups, which consisted of 10 samples.

The fatty acid composition of triglyceride (TG) and the phospholipid (PL) portions in beef LM was determined by separation of the TG and PL using thin-layer chromatography (See Appendix B). Total lipids were esterified from the LM samples with acetyl chloride/methanol for 1 h at 100ºC (Christie, 1972). The solution was allowed to cool and neutralized with 6% potassium carbonate. Methyl esters were subsequently extracted in hexane. Fatty acid methyl esters were analyzed using a gas chromatograph (model 3900, Varian Analytical Instruments, Walnut Creek, CA) fitted with a fused silica capillary column (Supelco, Bellefonte, PA). A temperature-programmed procedure was used (Sehat et al., 1998) and fatty acids were identified by evaluating the retention time against the GLC 461 standard obtained from Nu-Chek-Prep

(Elysian, MN). Fatty acid composition was calculated using the peak areas on a percentage basis. The index of atherogenicity (IA) was calculated according to Ulbricht and Southgate (1991).

Statistical Analysis

The correlation procedure of SAS (SAS Inst. Inc., Cary, NC) was used to generate Pearson phenotypic correlations among traits by location. Unadjusted means and standard deviations were obtained through PROC CORR of SAS. Significance was determined at $P < 0.05$ for analyses.

RESULTS AND DISCUSSION

Descriptive statistics on the carcass traits in the study are presented in Table 3.1. The average MS was 5.93 (range 4.33 to 9.00) and 5.90 (range 3.80 to 8.50) in California and Iowa, respectively. The average HCW was 335.5 kg (range 245.0 to 424.5 kg) and 322.2 kg (range 191.1 to 448.6 kg) in California and Iowa, respectively. Fat thickness at the 12^{th} rib averaged 1.32 cm (range 0.30 to 2.74 cm) and 1.08 cm (range 0.38 to 2.16 cm) in California and Iowa, respectively. The average LMA was 79.7 cm^2 (range 61.6 to 102.9 cm^2) and 79.5 cm^2 (range 58.7 to 107.1 cm^2) in California and Iowa, respectively. Calculated YG averaged 3.0 (range 1.2 to 5.0) and 2.7 (range 1.1 to 4.4) in California and Iowa, respectively. Descriptive statistics for WBS, sensory traits, and TBARS are shown in Table 3.2. Average WBS values were 3.65 (range 2.44 to 5.51) and 4.12 (range 2.54 to 7.21) in California and Iowa, respectively. Sustained juiciness dropped in both populations from 5.05 to 4.71 and 5.39 to 5.11 in California and Iowa, respectively. The average panelist rating for IT and OT in both populations was slightly tender. The beef

flavor intensity average was 2.46 and 2.42 in California and Iowa samples, respectively. The average PFF and LMF in both populations were 1.08 and 1.09, respectively.

Unadjusted means for mineral concentration are provided in Table 3.3. Potassium was the most abundant mineral in both populations, followed by phosphorus, sodium, magnesium, zinc, calcium, and iron. Copper and manganese make up only a small proportion of the total mineral content. According to USDA (2009), the average beef top loin steak is comprised of 3560 μg potassium, 2210 μg phosphorus, 590 μg sodium, 240 μg magnesium, 210 μg calcium, 51.5 μg zinc, 18.3 μg iron, 0.8 μg copper, and 0.1 μg manganese per g of meat. Both populations appear below average for a majority of these minerals, particularly potassium and phosphorus in the Iowa samples and calcium in both sets of samples.

Descriptive statistics for fatty acid composition are presented in Table 3.4. Oleic acid (C18:1) was the most abundant single fatty acid in both populations, comprising a majority of the MUFA concentration. Palmitic acid (C16:0) and stearic acid (C18:0) were the next most abundant fatty acids in both populations, followed by linoleic acid (C18:2), palmitoleic acid (C16:1), and myristic acid (C14:0). According to USDA (2009), C18:1 accounts for 44.8% of total fatty acids of beef top loin. Palmitic acid ranges between 27-28%, and stearic typically averages 15% of the total concentration of fatty acids in beef top loin. The remaining fatty acids are present anywhere from 1-4%, with C16:1 representing 4%, C14:0 at 3.5%, C18:2 at 3.3%, and C18:3 accounting for 0.7% of the total proportion of fatty acids in beef top loin (USDA, 2009). The average SFA concentration was 43.04 and 45.47 in the California and Iowa samples, respectively. The average MUFA concentration was 45.65 and 47.10, while PUFA averaged 6.31 and

5.37 in California and Iowa samples, respectively. The average beef top loin steak consists of 46.5% SFA, 49.1% MUFA, and 4.4% PUFA (USDA, 2009). Both populations appear to have higher PUFA concentrations than the national average, which is nutritionally desirable.

Pearson correlations between MS, WBS, sensory traits, and TBARS for California cattle are provided in Table 3.5. Generally, significant correlations were weak. Marbling score was significantly correlated ($P < 0.05$) with WBS, but that correlation was rather weak (r = - 0.196). There were strong positive correlations ($P < 0.05$) between IT, OT, and CT, with the largest between initial and overall tenderness (r = 0.929). The sensory tenderness traits (IT, OT, and CT) were moderately correlated ($P < 0.05$) with WBS in the negative direction. There was a strong positive correlation ($P < 0.05$) between IJ and SJ (r = 0.897). Beef flavor was significantly correlated ($P < 0.05$) with PFF (r = - 0.355) and LMF (r = - 0.253), but those correlations were relatively weak. There were no significant correlations ($P > 0.05$) between TBARS and any of the flavor intensities.

Pearson correlations between MS, WBS, sensory traits, and TBARS for Iowa cattle are provided in Table 3.6. As with the California cattle, marbling score was significantly correlated ($P < 0.05$) with WBS, but again that correlation was rather weak (r = - 0.208). Similarly, there were strong positive correlations ($P < 0.05$) between IT, OT, and CT, with the largest between initial and overall tenderness (r = 0.951). Again, the sensory tenderness traits were negatively correlated ($P < 0.05$) with WBS; however, the correlations were stronger in the Iowa samples than the California samples. This is in accordance with Shackelford et al. (1995), who found a strong relationship between peak

load and overall tenderness for the longissimus dorsi when they compared instrumental tenderness and trained sensory panel tenderness scores. There was a strong positive correlation ($P < 0.05$) between IF and SJ (r = 0.867). Beef flavor was significantly correlated ($P < 0.05$) with PFF (r = - 0.485) and LMF (r = - 0.253). The correlation between BF and LMF remained relatively weak, but the correlation between BF and PFF was stronger in Iowa samples when compared to California. Thiobarbituric acid reactive substances were significantly correlated ($P < 0.05$) with BF (r = 0.251) and PFF (r = - 0.231), but those correlations were relatively weak.

The current findings agree with Smith et al. (1984), who found steaks from carcasses with higher marbling scores had lower shear force values and higher sensory panel ratings than steaks with lower marbling scores. Wheeler et al. (1994) found a similar relationship between MS, WBS, and tenderness ratings. Wheeler et al. (1994) did not find a relationship between beef flavor and MS. In the current study, beef flavor was only significantly correlated with MS in the Iowa samples. Also in the present study, marbling score was correlated with IJ and SJ in the California cattle only. Wheeler et al. (1994) found steaks with modest or moderate marbling were juicier than steaks with traces or slight marbling, which supports the correlations found in the California samples.

Campo et al. (2006) found significant ($P < 0.001$) correlations (r = 0.84) between TBARS and rancid (r = 0.84), beef (r = - 0.80), metallic (r = - 0.36), and livery flavors (r = - 0.60), as well as overall liking (r = - 0.84). Although there were no significant correlations between TBARS and flavor intensities in the California samples, this contradicts the results of the current study for the Iowa samples. While Campo et al. (2006) determined a TBARS value of approximately 2 (expressed as mg of

malonaldehyde per kg of lean muscle) could be set as a threshold for acceptability of oxidized beef, it should be noted that the TBARS values were well below 2 in this study, averaging 0.16 and 0.19 in California and Iowa samples, respectively (Table 2). Samples in this study were aged 14 d postmortem in a vacuum package and frozen immediately, leaving little opportunity for lipid oxidation. Overall, low TBARS values could explain why little to no relationship was seen between TBARS and flavor intensities, especially the painty/fishy flavor.

Table 3.7 and Table 3.8 summarize the Pearson correlations between mineral concentrations and MS, WBS, sensory traits, and TBARS for California and Iowa cattle, respectively. In general, specific mineral concentrations did not demonstrate strong correlations with WBS, sensory traits, or TBARS. Furthermore, significant correlations were not consistent between the two cattle populations. For example, LMF was significantly correlated ($P < 0.05$) with copper, calcium, magnesium, phosphorus, potassium, and sodium in the California samples. Although those correlations were rather weak, there were no correlations between LMF and any of the minerals in the Iowa samples. Also, copper, potassium, and sodium were significantly correlated ($P < 0.05$) with the tenderness traits (WBS, IT, OT, and CT), all of which were desirable relationships, in the Iowa samples; however, only copper and sodium had a significant relationship ($P < 0.05$) with WBS values, but not IT, OT, or CT in the California samples. This difference between the two populations may be attributed to the higher numerical average of potassium and phosphorus content of the California samples.

Although Yancey et al. (2006) did not examine the LM, they did find liver flavor intensity increased and beef flavor intensity decreased in the gluteus medius as iron

content increased. However, livery flavor decreased as iron concentration increased in the psoas major. This demonstrates the inconsistent relationship between iron content and beef, livery, or metallic flavors. These findings are in agreement with the current study in that the relationships that did exist were relatively low.

To estimate the extent to which lipid composition influenced beef palatability, correlations between fatty acid profiles and MS, WBS, sensory traits, and TBARS were determined for California (Table 3.9) and Iowa (Table 3.10) cattle. Marbling score was significantly correlated ($P < 0.05$) with C18:2 (r = - 0.189), C18:3n-3 (r = 0.111), C18:3n-6 (r = 0.178), PUFA (r = - 0.198), PUFA:SFA (r = - 0.188), and the sum of n-6 fatty acids (r = - 0.211) in California cattle, but correlations were relatively weak. In Iowa samples, marbling score was significantly correlated ($P < 0.05$) with C14:0 (r = 0.189), C16:0 (r = 0.174), C16:1 (r = 0.275), C18:1 (r = 0.260), C18:2 (r = - 0.427), MUFA (r = 0.272), PUFA (r = - 0.207), and the sum of n-6 fatty acids (r = - 0.380). Only C18:2, PUFA, and the sum of n-6 fatty acids were significantly correlated to marbling score in both populations. Kazala et al. (1999) found a similar trend in C18:2; however, they also saw a negative correlation between the concentration of 18:0 and marbling score, which does not agree with the findings of the current study.

Linoleic acid (C18:2) was the only fatty acid that was significantly correlated ($P < 0.05$) with WBS in the California samples, but the correlation was relatively weak (r = 0.124). In the Iowa population, WBS was significantly correlated ($P < 0.05$) with C18:1 (r = - 0.144), C18:2 (r = 0.159), C18:3n-3 (r = - 0.287), C18:3n-6 (r = -0.142), and MUFA (r = - 0.148).

No significant correlations ($P > 0.05$) existed between initial or sustained juiciness and any of the major beef fatty acids in the California cattle. In the Iowa samples, IJ and SJ were negatively correlated ($P < 0.05$) with C16:0, C18:0, C18:1, C18:2, SFA, MUFA, and sum of n-6 fatty acids, but those correlations were all relatively weak.

Linolenic acid (C18:3n-3) was the only fatty acid that was significantly correlated ($P < 0.05$) with IT (r = - 0.105), OT (r = - 0.114), and CT (r = - 0.210) in the California population; however, it was the only fatty acid with a significant ($P < 0.05$) positive correlation (r = 0.151) to OT in the Iowa population. Initial tenderness was significantly correlated ($P < 0.05$) with C14:0 (r = - 0.208), C16:0 (r = - 0.223), C18:0 (r = - 0.173), C18:2 (r = - 0.184), SFA (r = - 0.224), and the sum of n-6 fatty acids (r = - 0.161) in the Iowa samples, but those correlations were all relatively weak. Other than the positive correlation of linolenic acid, C14:0, C18:2, and the sum of n-6 fatty acids were negatively correlated ($P < 0.05$) with OT.

Although correlations were relatively weak, beef flavor was positively correlated ($P < 0.05$) with C14:0, C16:0, C18:1, and MUFA in both populations. Linoleic acid (C18:2) was negatively correlated ($P < 0.05$) with beef flavor in California samples only, and represented the only significant negative correlation with beef flavor in either population. Painty/fishy flavor was negatively correlated ($P < 0.05$) with C18:2, PUFA, and the sum of n-6 fatty acids in California samples, but was positively correlated ($P < 0.05$) with the same traits in the Iowa samples. There were no consistent relationships between lipid composition and LMF between the two populations. Dryden and Marchello (1970) found C18:1 was positively correlated with flavor, which is similar to

the current findings. However, Westerling and Hedrick (1979) determined flavor was negatively correlated with C16:0, C18:0, C18:2, and SFA, which contradicts the positive correlation of the current study between beef flavor and C16:0.

Linolenic acid (C18:3n-3) was the only fatty acid that was significantly correlated ($P < 0.05$) with TBARS in both locations; however, the relationship is opposite in the two populations. Thiobarbituric acid reactive substances were significantly correlated ($P < 0.05$) with C18:3n-3 (r = - 0.103) in California and with C18:0 (r = - 0.200), C18:1 (r = 0.219), C18:3n-3 (r = 0.412), C18:3n-6 (r = 0.145), and MUFA (r = 0.222) in the Iowa samples.

CONCLUSION

As expected, marbling score was correlated to WBS values in both populations. However, marbling score was only related to initial and overall tenderness in the California samples. Furthermore, marbling score was only related to beef flavor in the Iowa Samples. Strong correlations existed between initial and sustained juiciness, as well as between the tenderness traits in both populations.

In general, specific fatty acids and minerals did not demonstrate strong correlations with beef palatability traits. Although there were significant correlations between traits, there was a lack of consistency between the two populations. Based on these results, it appears as though tenderness, juiciness, and flavor are not strongly influenced by the nutrient components in beef longissimus in Angus cattle.

Table 3.1. Number of records and unadjusted means (± SD) for carcass traits by location.

	California		Iowa	
Trait	No. of animals	Mean	No. of animals	Mean
HCW, kg	382	335.47 ± 31.94	194	322.25 ± 38.27
Fat thickness, cm	382	1.32 ± 0.45	194	1.08 ± 0.31
LM area, cm^2	382	79.66 ± 6.57	194	79.52 ± 6.98
KPH, %	382	1.92 ± 0.21	194	1.99 ± 0.37
USDA calculated YG	382	3.04 ± 0.68	194	2.71 ± 0.51
Marbling score[1]	382	5.93 ± 0.93	194	5.90 ± 0.90

[1]3.0 = traces; 4.0 = slight; 5.0 = small; 6.0 = modest; 7.0 = moderate; 8.0 = slightly abundant; 9.0 = moderately abundant.

Table 3.2. Number of records and unadjusted means (± SD) for Warner-Bratzler Shear force (WBS), trained sensory traits, and thiobarbituric acid reactive substances (TBARS) by location.

	California		Iowa	
Trait	No. of animals	Mean	No. of animals	Mean
WBS, kg	361	3.65 ± 0.51	194	4.12 ± 0.82
Initial juiciness[1]	359	5.05 ± 0.46	194	5.39 ± 0.37
Sustained juiciness[1]	359	4.71 ± 0.47	194	5.11 ± 0.36
Initial tenderness[1]	359	5.76 ± 0.45	194	5.62 ± 0.63
Overall tenderness[1]	359	5.81 ± 0.44	194	5.63 ± 0.62
Connective tissue[2]	359	5.99 ± 0.47	194	5.70 ± 0.64
Beef flavor[3]	359	2.46 ± 0.20	194	2.42 ± 0.22
Painty/fishy flavor[3]	359	1.08 ± 0.12	194	1.08 ± 0.12
Livery/metallic flavor[3]	359	1.09 ± 0.12	194	1.09 ± 0.11
TBARS, mg/kg[4]	358	0.16 ± 0.03	194	0.19 ± 0.05

[1]1 = extremely dry, extremely tough; 8 = extremely juicy, extremely tender.
[2]1 = abundant; 8 = none.
[3]1 = not detectable; 3 = strong.
[4]Expressed as mg of malonaldehyde per kg of sample.

Table 3.3. Number of records and unadjusted means (± SD) for mineral concentration by location.

	California		Iowa	
Trait[1]	No. of animals	Mean	No. of animals	Mean
Calcium, μg	358	37.91 ± 38.78	194	32.37 ± 17.51
Copper, μg	358	0.35 ± 0.62	194	0.52 ± 0.30
Iron, μg	358	11.99 ± 2.65	194	13.81 ± 2.68
Magnesium, μg	358	238.34 ± 21.76	194	210.17 ± 24.02
Manganese, μg	358	0.03 ± 0.06	194	0.04 ± 0.04
Phosphorus, μg	358	1931.00 ± 139.60	194	1628.00 ± 320.39
Potassium, μg	358	3420.00 ± 299.79	194	2823.00 ± 875.87
Sodium, μg	358	481.27 ± 45.06	194	425.27 ± 73.08
Zinc, μg	358	37.82 ± 5.39	194	38.36 ± 12.91

[1]Expressed as μg of mineral per g of wet meat sample.

Table 3.4. Number of records and unadjusted means (± SD) for fatty acid composition by location.

	California		Iowa	
Trait	No. of animals	Mean	No. of animals	Mean
C10:0	360	0.06 ± 0.06	194	0.05 ± 0.03
C12:0	360	0.09 ± 0.06	194	0.04 ± 0.03
C13:0	360	0.01 ± 0.02	194	0.01 ± 0.03
C14:0	360	2.98 ± 0.85	194	2.52 ± 0.59
C14:1	360	0.67 ± 0.25	194	0.52 ± 0.20
C15:0	360	0.59 ± 0.17	194	0.29 ± 0.10
C16:0	360	25.11 ± 5.93	194	26.65 ± 4.22
C16:1	360	3.16 ± 1.10	194	3.21 ± 0.69
C17:0	360	1.59 ± 0.43	194	0.97 ± 0.21
C17:1	360	1.38 ± 0.43	194	0.69 ± 0.23
C18:0	360	11.55 ± 2.95	194	14.62 ± 2.86
cis-9 C18:1	360	35.87 ± 8.60	194	38.24 ± 6.28
cis-11 C18:1	360	0.15 ± 0.16	194	0.14 ± 0.11
cis-12 C18:1	360	0.15 ± 0.14	194	0.28 ± 0.15
cis-13 C18:1	360	0.09 ± 0.07	194	0.11 ± 0.08
trans-6 C18:1	360	0.00 ± 0.00	194	0.00 ± 0.01
trans-9 C18:1	360	0.03 ± 0.38	194	0.07 ± 0.14
trans-10/11 C18:1	360	3.37 ± 1.83	194	2.48 ± 1.21
trans-12 C18:1	360	0.04 ± 0.53	194	0.07 ± 0.22
trans-15 C18:1	360	0.49 ± 0.58	194	1.26 ± 0.30
C18:1[1]	360	37.88 ± 13.14	194	41.57 ± 9.46
C18:2	360	3.82 ± 1.39	194	3.68 ± 1.34
cis-9, *trans*-11 C18:2[2]	360	0.11 ± 0.15	194	0.16 ± 0.12
trans-10, *cis*-12 C18:2[2]	360	0.02 ± 0.02	194	0.01 ± 0.01
C18:3[3]	360	0.26 ± 0.23	194	0.23 ± 0.17
C18:3[4]	360	0.04 ± 0.04	194	0.01 ± 0.01
C20:0	360	0.02 ± 0.02	194	0.06 ± 0.05
C20:1	360	0.24 ± 0.08	194	0.04 ± 0.04
C20:2	360	0.07 ± 0.05	194	0.09 ± 0.53
C20:3[3]	360	0.01 ± 0.02	194	0.00 ± 0.01
C20:3[4]	360	0.05 ± 0.15	194	0.01 ± 0.07
C20:4	360	0.82 ± 0.38	194	0.82 ± 0.37
C20:5	360	0.46 ± 0.56	194	0.04 ± 0.05
C22:0	360	0.27 ± 0.12	194	0.21 ± 0.10
C22:1	360	0.01 ± 0.08	194	0.00 ± 0.01
C22:4	360	0.18 ± 0.27	194	0.12 ± 0.08
C22:5	360	0.23 ± 0.27	194	0.03 ± 0.07
C22:6	360	0.26 ± 0.30	194	0.18 ± 2.30
C23:0	360	0.26 ± 0.36	194	0.02 ± 0.06
C24:0	360	0.52 ± 0.80	194	0.05 ± 0.09
SFA	360	43.04 ± 10.09	194	45.47 ± 7.13

MUFA	360	45.65 ± 10.71	194	47.10 ± 7.42
PUFA	360	6.31 ± 2.34	194	5.37 ± 2.75
PUFA:SFA	360	0.14 ± 0.06	194	0.12 ± 0.08
MCFA (<C15:1)	360	4.40 ± 1.27	194	3.43 ± 0.81
LCFA	360	90.60 ± 20.83	194	94.51 ± 13.76
Σ n-3 fatty acids	360	1.21 ± 0.97	194	0.49 ± 2.30
Σ n-6 fatty acids	360	5.10 ± 1.78	194	4.88 ± 1.73
n-3:n-6 ratio	360	0.24 ± 0.25	194	0.14 ± 1.03
IA[5]	360	0.68 ± 0.17	194	0.69 ± 0.13

[1]C18:1 = *cis*-9 C18:1 + *cis*-11 C18:1 + *cis*-12 C18:1 + *cis*-13 C18:1 + *trans*-6 C18:1 + *trans*-9 C18:1 + *trans*-10/11 C18:1 + *trans*-12 C18:1 + *trans*-15 C18:1.
[2]Conjugated linoleic acid.
[3]n-3 fatty acids.
[4]n-6 fatty acids.
[5]Index of atherogenicity, calculated as (4 x C14:0 + C16:0)/(*Σ* MUFA + *Σ* PUFA).

Table 3.5. Pearson correlations between marbling score, Warner-Bratzler Shear force (WBS), trained sensory traits, and thiobarbituric acid reactive substances (TBARS) of beef LM for California cattle[1] (n = 359).

	WBS	IJ	SJ	IT	OT	CT	BF	PFF	LMF	TBARS
Marbling score (MS)	**- 0.196**	**0.181**	**0.188**	**0.103**	**0.102**	0.061	- 0.035	**0.124**	0.040	0.015
WBS, kg		- 0.086	- 0.072	**- 0.469**	**- 0.488**	**- 0.458**	0.024	0.050	- 0.097	**- 0.247**
Initial juiciness (IJ)			**0.897**	**0.333**	**0.272**	**0.118**	**- 0.187**	**0.126**	0.072	0.025
Sustained juiciness (SJ)				**0.307**	**0.267**	**0.121**	**- 0.143**	**0.154**	0.086	0.015
Initial tenderness (IT)					**0.929**	**0.770**	- 0.063	0.024	- 0.001	**0.106**
Overall tenderness (OT)						**0.865**	- 0.008	0.014	0.002	**0.110**
Connective tissue (CT)							0.016	- 0.019	- 0.032	0.062
Beef flavor (BF)								**- 0.355**	**- 0.253**	0.047
Painty/fishy flavor (PFF)									0.017	0.001
Livery/metallic flavor (LMF)										- 0.021

[1]Significant correlations are shown in bold ($P < 0.05$).

Table 3.6. Pearson correlations between marbling score, Warner-Bratzler Shear force (WBS), trained sensory traits, and thiobarbituric acid reactive substances (TBARS) of beef LM for Iowa cattle[1] (n = 194).

	WBS	IJ	SJ	IT	OT	CT	BF	PFF	LMF	TBARS
Marbling score (MS)	**- 0.208**	0.095	0.046	- 0.014	0.039	0.061	**0.207**	**- 0.239**	- 0.046	0.126
WBS, kg		**- 0.169**	- 0.086	**- 0.687**	**- 0.739**	**- 0.696**	- 0.048	**0 139**	**- 0.143**	**- 0.303**
Initial juiciness (IJ)			**0.867**	**0.413**	**0.348**	**0.248**	**- 0.168**	0.075	**0.303**	0.018
Sustained juiciness (SJ)				**0.355**	**0.308**	**0.232**	**- 0.222**	0.135	**0.264**	- 0.037
Initial tenderness (IT)					**0.951**	**0.858**	- 0.129	- 0.053	**0.159**	**0.168**
Overall tenderness (OT)						**0.924**	- 0.092	- 0.066	**0.180**	**0.173**
Connective tissue (CT)							- 0.068	- 0.076	**0.175**	**0.145**
Beef flavor (BF)								**- 0.485**	**- 0.233**	**0.251**
Painty/fishy flavor (PFF)									- 0.018	**- 0.231**
Livery/metallic flavor (LMF)										- 0.012

[1]Significant correlations are shown in bold ($P < 0.05$).

Table 3.7. Pearson correlations between mineral concentrations and marbling score, Warner-Bratzler Shear force (WBS), trained sensory traits, and thiobarbituric acid reactive substances (TBARS) of beef LM for California cattle[1] (n = 358).

Mineral	Marbling score	WBS	Initial juiciness	Sustained juiciness	Initial tenderness	Overall tenderness	Connective tissue	Beef flavor	Painty/ fishy flavor	Livery/ metallic flavor	TBARS
Calcium	- 0.094	- 0.047	- 0.029	- 0.076	- 0.005	- 0.013	0.029	**- 0.115**	0.009	0.074	0.061
Copper	- 0.018	**- 0.152**	- 0.076	- 0.054	0.029	0.014	0.076	- 0.091	0.095	**0.123**	- 0.003
Iron	0.046	- 0.058	- 0.023	- 0.036	- 0.042	- 0.036	- 0.002	0.060	0.012	**0.154**	**0.227**
Magnesium	**- 0.106**	- 0.011	- 0.060	- 0.087	- 0.101	**- 0.120**	**- 0.123**	0.041	**- 0.119**	**0.109**	- 0.019
Manganese	0.020	**- 0.121**	- 0.031	- 0.041	- 0.017	- 0.018	0.053	**- 0.109**	0.061	0.092	0.076
Phosphorus	**- 0.178**	- 0.008	- 0.066	- 0.069	- 0.072	- 0.082	- 0.070	0.027	- 0.050	**0.104**	- 0.054
Potassium	**- 0.121**	- 0.033	- 0.066	- 0.056	- 0.009	- 0.021	- 0.014	- 0.054	- 0.060	**0.158**	0.030
Sodium	0.013	**- 0.161**	0.036	0.040	0.045	0.054	0.040	- 0.016	- 0.023	**0.125**	0.085
Zinc	- 0.070	0.041	- 0.003	0.033	**- 0.124**	**- 0.111**	**- 0.111**	0.017	0.048	- 0.006	**0.184**

[1]Significant correlations are shown in bold ($P < 0.05$).

Table 3.8. Pearson correlations between mineral concentrations and marbling score, Warner-Bratzler Shear force (WBS), trained sensory traits, and thiobarbituric acid reactive substances (TBARS) of beef LM for Iowa cattle[1] (n = 194).

Mineral	Marbling score	WBS	Initial juiciness	Sustained juiciness	Initial tenderness	Overall tenderness	Connective tissue	Beef flavor	Painty/ fishy flavor	Livery/ metallic flavor	TBARS
Calcium	0.115	- 0.111	- 0.125	0.122	0.125	**0.142**	0.123	0.033	- 0.068	0.005	- 0.098
Copper	**0.161**	**- 0.345**	0.066	0.047	**0.251**	**0.267**	**0.255**	**0.165**	**- 0.267**	- 0.008	**0.161**
Iron	0.025	0.019	- 0.100	- 0.067	- 0.012	- 0.022	- 0.004	0.018	- 0.112	- 0.054	- 0.064
Magnesium	**- 0.136**	- 0.026	- 0.106	- 0.067	0.064	0.066	0.089	- 0.127	0.034	0.004	**- 0.184**
Manganese	**- 0.209**	0.051	0.004	0.045	0.030	0.026	0.039	- 0.068	0.058	0.057	- 0.118
Phosphorus	**- 0.191**	0.006	- 0.026	- 0.023	0.024	- 0.011	- 0.010	- 0.121	0.009	0.026	0.074
Potassium	**0.193**	**- 0.230**	0.003	- 0.071	**0.139**	**0.162**	**0.192**	0.069	**- 0.149**	0.086	**0.140**
Sodium	**0.241**	**- 0.204**	- 0.055	- 0.045	**0.148**	**0.189**	**0.203**	- 0.035	- 0.046	- 0.028	- 0.040
Zinc	0.049	- 0.021	0.000	0.010	0.017	0.006	0.014	0.025	0.049	0.010	**- 0.158**

[1]Significant correlations are shown in bold ($P < 0.05$).

Table 3.9. Pearson correlations between fatty acid composition and marbling score, Warner-Bratzler Shear force (WBS), trained sensory traits, and thiobarbituric acid reactive substances (TBARS) of beef LM for California cattle[1] (n = 359).

Fatty acid	Marbling score	WBS	Initial juiciness	Sustained juiciness	Initial tenderness	Overall tenderness	Connective tissue	Beef flavor	Painty/ fishy flavor	Livery/ metallic flavor	TBARS
C14:0	0.025	- 0.034	0.089	0.087	- 0.003	0.015	- 0.038	**0.149**	- 0.087	- 0.009	0.083
C16:0	- 0.015	- 0.045	0.067	0.079	- 0.008	0.016	- 0.032	**0.128**	- 0.086	- 0.027	0.097
C16:1	0.023	- 0.041	0.080	0.079	0.019	0.018	- 0.027	0.100	- 0.049	- 0.051	0.101
C18:0	- 0.058	- 0.041	0.007	0.036	- 0.012	0.026	- 0.006	**0.113**	- 0.040	- 0.052	0.069
C18:1[2]	0.043	- 0.018	0.053	0.068	0.007	0.042	- 0.006	**0.125**	- 0.099	- 0.049	0.069
C18:2	**- 0.189**	0.029	- 0.019	- 0.031	- 0.019	- 0.003	- 0.030	0.078	**- 0.117**	0.016	0.093
C18:3[3]	**0.111**	**0.124**	0.072	0.046	**- 0.105**	**- 0.114**	**- 0.210**	**0.295**	**- 0.147**	**- 0.133**	**- 0.103**
C18:3[4]	**0.178**	- 0.035	- 0.005	0.018	0.011	0.026	0.026	**0.135**	0.014	**- 0.101**	0.029
SFA	- 0.034	- 0.052	0.047	0.060	- 0.010	0.021	- 0.025	**0.119**	- 0.069	- 0.027	0.091
MUFA	- 0.004	- 0.038	0.062	0.076	0.010	0.042	- 0.008	**0.126**	- 0.096	- 0.051	0.077
PUFA	**- 0.198**	0.039	- 0.010	- 0.042	- 0.037	- 0.025	- 0.090	0.086	**- 0.127**	0.003	0.009
PUFA:SFA	**- 0.188**	0.047	- 0.008	- 0.041	- 0.034	- 0.022	- 0.089	0.086	**- 0.134**	- 0.006	- 0.002
Σ n-3 fatty acids	- 0.090	0.047	0.016	- 0.021	- 0.037	- 0.037	**- 0.127**	0.073	**- 0.108**	- 0.039	**- 0.122**
Σ n-6 fatty acids	**- 0.211**	0.025	- 0.022	- 0.043	- 0.029	- 0.012	- 0.049	0.074	**- 0.108**	0.025	0.079
n-3:n-6 ratio	0.045	- 0.018	0.064	0.047	- 0.008	- 0.011	- 0.093	**0.117**	- 0.057	- 0.045	- 0.088
IA[5]	- 0.003	- 0.051	0.072	0.080	- 0.012	0.010	- 0.035	**0.131**	- 0.070	- 0.012	**0.104**

[1]Significant correlations are shown in bold ($P < 0.05$).
[2]C18:1 = *cis*-9 C18:1 + *cis*-11 C18:1 + *cis*-12 C18:1 + *cis*-13 C18:1 + *trans*-6 C18:1 + *trans*-9 C18:1 + *trans*-10/11 C18:1 + *trans*-12 C18:1 + *trans*-15 C18:1.
[3]n-3 fatty acids.
[4]n-6 fatty acids.
[5]Index of atherogenicity.

Table 3.10. Pearson correlations between fatty acid composition and marbling score, Warner-Bratzler Shear force (WBS), trained sensory traits, and thiobarbituric acid reactive substances (TBARS) of beef LM for Iowa cattle[1] (n = 194).

Fatty acid	Marbling score	WBS	Initial juiciness	Sustained juiciness	Initial tenderness	Overall tenderness	Connective tissue	Beef flavor	Painty/ fishy flavor	Livery/ metallic flavor	TBARS
C14:0	**0.189**	0.017	- 0.123	**- 0.141**	**- 0.208**	**- 0.153**	- 0.133	**0.144**	0.005	**- 0.153**	- 0.104
C16:0	**0.174**	0.004	**- 0.191**	**- 0.216**	**- 0.223**	- 0.134	- 0.083	**0.156**	0.017	- 0.130	- 0.018
C16:1	**0.275**	- 0.118	- 0.116	- 0.133	- 0.129	- 0.069	- 0.049	0.138	- 0.026	- 0.100	0.106
C18:0	- 0.126	0.114	**- 0.174**	**- 0.145**	**- 0.173**	- 0.108	- 0.067	- 0.018	0.125	- 0.025	**- 0.200**
C18:1[2]	**0.260**	**- 0.144**	**- 0.145**	**- 0.177**	- 0.081	0.020	0.060	**0.196**	- 0.078	- 0.073	**0.219**
C18:2	**- 0.427**	**0.159**	**- 0.200**	**- 0.185**	**- 0.184**	**- 0.179**	**- 0.170**	**- 0.149**	**0.229**	- 0.005	- 0.041
C18:3[3]	0.087	**- 0.287**	- 0.070	- 0.073	0.137	**0.151**	0.081	0.057	- 0.107	0.043	**0.412**
C18:3[4]	- 0.052	**- 0.142**	- 0.051	- 0.026	0.137	0.127	0.061	- 0.029	0.078	0.015	**0.145**
SFA	0.069	0.046	**- 0.194**	**- 0.200**	**- 0.224**	- 0.138	- 0.090	0.095	0.066	- 0.100	- 0.091
MUFA	**0.272**	**- 0.148**	**- 0.147**	**- 0.178**	- 0.091	0.010	0.049	**0.196**	- 0.075	- 0.079	**0.222**
PUFA	**- 0.207**	0.075	- 0.084	- 0.063	- 0.118	- 0.124	- 0.107	- 0.084	**0.153**	0.040	- 0.033
PUFA:SFA	- 0.128	0.041	- 0.039	- 0.022	- 0.081	- 0.090	- 0.072	- 0.065	0.108	0.044	0.001
Σ n-3 fatty acids	0.039	- 0.001	0.063	0.067	- 0.020	- 0.035	- 0.019	- 0.052	0.021	0.025	- 0.007
Σ n-6 fatty acids	**- 0.380**	0.121	**- 0.218**	**- 0.190**	**- 0.161**	**- 0.153**	**- 0.146**	- 0.064	**0.216**	0.030	- 0.044
n-3:n-6 ratio	0.052	0.007	0.070	0.075	- 0.021	- 0.035	- 0.017	- 0.050	0.018	0.023	- 0.020
IA[5]	0.130	0.066	**- 0.165**	**- 0.179**	**- 0.244**	**- 0.174**	- 0.132	0.126	0.044	**- 0.145**	**- 0.152**

[1]Significant correlations are shown in bold ($P < 0.05$).
[2]C18:1 = *cis*-9 C18:1 + *cis*-11 C18:1 + *cis*-12 C18:1 + *cis*-13 C18:1 + *trans*-6 C18:1 + *trans*-9 C18:1 + *trans*-10/11 C18:1 + *trans*-12 C18:1 + *trans*-15 C18:1.
[3]n-3 fatty acids.
[4]n-6 fatty acids.
[5]Index of atherogenicity.

CHAPTER IV

EFFECT OF CONCENTRATE- VS. FORAGE-BASED FINISHING DIET ON CARCASS TRAITS, BEEF PALATABILITY, AND COLOR STABILITY IN LONGISSIMUS FROM ANGUS HEIFERS

ABSTRACT

The objective of the study was to determine the effect of finishing diet on carcass traits, beef palatability, and color stability in longissimus from Angus heifers. Half-sibs were obtained from a herd involved in selection for increased IMF, ribeye area, and retail product, and decreased back fat and alternatively assigned to a forage- or concentrate-based finishing diet. Longissimus muscle samples were obtained and fabricated into steaks for trained sensory panel, Warner-Bratzler Shear force (WBS), thiobarbituric acid reactive substances (TBARS), and simulated retail display. Analysis of variance was conducted through the MIXED procedure of SAS using harvest age as a covariate. Carcasses from heifers finished on concentrate had greater adjusted fat thickness, higher percentage KPH, higher numerical yield grades, and higher marbling scores ($P < 0.05$) than forage finished heifers. There was no difference in LMA between diets ($P > 0.05$). Steaks from concentrate-fed heifers had lower WBS values, higher tenderness ratings, higher beef flavor intensity, lower grassy/cowy flavor intensity, and higher painty/fishy

flavor intensity than steaks from forage-fed heifers ($P < 0.05$). There was no difference ($P > 0.05$) between diets for initial or sustained juiciness and livery/metallic flavor intensity. Initial TBARS were higher ($P < 0.05$) in steaks from concentrate-fed heifers when compared to grass-fed heifers, but TBARS were not different ($P > 0.05$) between diets following 7 d in retail display. Generally, diet did not have an effect on instrumental or subjective color, except L* values were higher ($P < 0.05$) for steaks from concentrate-fed heifers than from forage-fed heifers. Although incorporating forages into beef finishing diets can be beneficial from a human nutritional standpoint, this study demonstrates there are still several hurdles to overcome in relation to beef palatability, especially tenderness and beef flavor.

INTRODUCTION

Beef is known for its superior eating quality over other protein sources; however, it can be classified as a fatty protein source with certain health risks associated with its consumption. Today's typical consumers desire safe, flavorful, and healthy meat products, and so considerable attention has been given to the improvement of the nutritional value of beef, particularly through the diet and genetic selection.

Fatty acid profiles in intramuscular fat can be altered and enhanced for human nutrition by incorporating grass in the diet (French et al., 2000; Realini et al., 2004). Higher grass intake can decrease the concentration of SFA, while increasing the ratio of polyunsaturated fatty acids to saturated fatty acids (PUFA:SFA) and the concentration of beneficial conjugated linoleic acid.

While forage-based finishing systems can enhance the nutritional value of beef, their effect on carcass characteristics, palatability traits, and color stability remains

mixed. In addition to increasing IMF in the LD (Faucitano et al., 2008), grain feeding can also increase carcass weight and backfat (Mandell et al., 1998; Realini et al., 2004). French et al. (2001) found no differences in color, tenderness, or sensory traits between diets of varying levels of grass and concentrates. However, Faucitano et al. (2008) reported decreased sensory panel tenderness scores for grain-fed cattle, but Schroeder et al. (1980) found grain-finishing increased scores for palatability determining traits, while reducing WBS values. The effect of diet on color stability and lipid oxidation varies depending on the processed state of the muscle (Realini et al., 2004).

Results in these types of studies can be confounded by backfat finish or harvest age. Therefore, the purpose of this study was to examine the effects of concentrate- vs. forage- finishing on carcass characteristics, beef palatability, and color stability when fed to a common end-point, while statistically accounting for harvest age.

MATERIALS AND METHODS

The Oklahoma State University Institutional Review Board (IRB) approved the experimental protocol used in the present study (See Appendix A).

Animal Resources and Diets

Angus heifers (n = 206) utilized in this study were obtained from a herd in South Carolina that has been selected for increased IMF, ribeye area, and retail product, and decreased back fat since 1993. Paternal half-siblings were alternatively assigned to a concentrate- or forage-based finishing diet. All heifers were backgrounded on wheat pasture until March 2008 in central Oklahoma. Following backgrounding, concentrate-finished heifers were fed naturally (no implants or antibiotics) at a commercial feedlot in the Texas panhandle for approximately 140 d. Forage-finished heifers were rotated

between grass and wheat pasture with an antibiotic-free mineral supplement until July 2009. Heifers had access to wheat pasture and dormant grass during winter months and Bermuda and native grasses during the warm seasons.

Harvest and Data Collection

Cattle were harvested at two commercial harvest facilities in Texas between July 2008 and July 2009. Trained personnel obtained carcass measurements, including hot carcass weight (HCW), ribeye area (LMA), marbling score (MS), percentage kidney, pelvic, and heart fat (KPH), adjusted fat thickness (FAT), calculated USDA yield grade (YG), and USDA quality grade. The scale used for data entry of MS was 10 = practically devoid, 20 = traces, 30 = slight, 40 = small, 50 = modest, 60 = moderate, 70 = slightly abundant, and 80 = moderately abundant.

Sample Collection and Preparation

Carcasses were fabricated according to Institutional Meat Purchasing Specifications (IMPS; USDA, 1996). Strip loins (IMPS #180) were collected, vacuum packaged, boxed, and transported back to the Oklahoma State University (OSU) Food and Agricultural Products Center (FAPC), Stillwater. Strip loins were aged 10 d postmortem at 2ºC. After aging, the anterior end of the strip loin was faced. The face steak was trimmed of all connective tissue and external fat to be used as the initial thiobarbituric acid reactive substances (TBARS) steak. Three 2.54 cm steaks were removed for WBS, sensory analysis, and simulated retail display. Sensory, WBS, and TBARS steaks were vacuum packaged and placed in a freezer at -20ºC for subsequent analysis.

Retail Display

Steaks were placed on a white styrofoam tray with a white soaker pad and were over-wrapped with a polyvinyl chloride film (PVC). To simulate retail display, trays were placed in an open topped, coffin-chest display case (M1-8EB, Hussman, Bridgeton, MO) maintained between 2 and 4° C, and were displayed under continuous, 1,600 lux of cool-white, fluorescent lighting (Bulb No. F40 T12, Promolux, BC, Canada).

Visual Color

Beginning at 0 h under display conditions and every 12 h thereafter for 7 d, each steak was subjectively evaluated by a six-member trained panel. Panelists were trained using Munsell color tiles and were required to receive a passing score before participating on a color panel. Trays were rotated daily to be exposed to all possible light angles and intensities, as well decrease potential environmental effects associated with the defrost cycle and location within the case. Panelists assigned scores to each steak for muscle color, surface discoloration, and overall appearance at each evaluation time. Muscle color was characterized on an 8-point scale (1 = extremely dark red, and 8 = extremely bright cherry red) as outlined in the Guidelines for Meat Color Evaluation (AMSA, 1991). Scores for surface discoloration were assigned based on a 7-point scale [1 = no (0%) discoloration, and 7 = total (100%) discoloration]. Overall appearance was scored on an 8-point scale (1 = extremely undesirable and 8 = extremely desirable).

Instrumental Color

Steaks were evaluated for instrumental color beginning at 0 h under display conditions and every 12 h thereafter for 7 d. The color of each steak was measured using a HunterLab Miniscan XE Plus Spectrophotometer (2.50-cm aperture, 10º standard observer, Illuminant D65, HunterLab Associates Inc., Reston, VA) to determine color

coordinate values for L* (brightness, 0 = black and 100 = white), a* (redness/greenness, positive values = red and negative values = green), and b* (yellowness/blueness, positive values = yellow and negative values = blue) according to the procedures of the Commission Internationale d'Eclairage (CIE, 1976). At each time of evaluation, three independent readings for L*, a*, and b* values were taken for each steak and averaged.

Warner Bratzler Shear Force (WBS)

The frozen steaks were allowed to temper at 4ºC for 24 h prior to cooking. Steaks were broiled in an impingement oven (XLT Impinger, Model 3240-TS, BOFI Inc., Wichita, KS or Lincoln Impinger, Model 1132-000-A, Lincoln Foodservice Products, Fort Wayne, IN) at 200ºC to an internal temperature of 68ºC. An Atkins AccuTuff 340 thermometer (Atkins Temtec, Gainesville, FL) was used to measure the temperature of steaks as they exited the oven. If they had not yet reached 68ºC, they were returned to the conveyor until they reached 68ºC. After cooking, steaks were cooled at 4ºC for 18 to 24 h. Six cores, 1.27 cm in diameter, were removed parallel to muscle fiber orientation and sheared once, using a Warner-Bratzler head attached to an Instron Universal Testing Machine (Model 4502, Instron Corporation, Canton, MS). The Warner-Bratzler head moved at a crosshead speed of 200 mm/min. Peak load (kg) of each core was recorded by an IBM PS2 (Model 55 SX) using software provided by the Instron Corporation. Mean peak load (kg) was analyzed for each sample.

Sensory Analysis

Steaks were assigned a randomized number for sensory sessions. Steaks were allowed to temper at 4ºC for 24 h prior to cooking, cooked to 68°C as described above for

WBS, sliced into approximately 2.54-cm × 1.27-cm × 1.27-cm samples, and served warm to panelists.

Sensory attributes were evaluated by an eight member, trained panel consisting of Oklahoma State University personnel. Panelists were trained for tenderness, juiciness, and four specific flavor attributes (Cross et al., 1978). Sensory sessions were conducted once or twice a day and contained 12 samples each. Samples were evaluated using a standard ballot from the American Meat Science Association (AMSA, 1995). Panelists evaluated samples in duplicate for initial (IJ) and sustained juiciness (SJ), initial (IT) and overall tenderness (OT), and amount of connective tissue (CT) using an 8-point scale. Panelists evaluated cooked beef flavor (BF), grassy/cowy flavor (GCF), painty/fishy flavor (PFF), and livery/metallic flavor (LMF) intensity using a 3-point scale. For juiciness, the scale was 1 = extremely dry and 8 = extremely juicy. The scale used for initial and overall tenderness was 1 = extremely tough and 8 = extremely tender. The scale used for connective tissue was 1 = abundant and 8 = none. The scale used for beef flavor and off-flavor intensity was 1 = not detectable, 2 = slightly detectable, and 3 = strong.

During sessions, panelists were randomly seated in individual booths in a temperature and light controlled room. While being served, the panelists were under red filtered lights as suggested by the American Meat Science Association (AMSA, 1995). The 12 samples were served in a randomized order according to panelist. The panelists were provided distilled, deionized water and unsalted crackers to cleanse their palate.

Thiobarbituric Acid Reactive Substances (TBARS)

Following retail display, steaks were removed from packaging and designated as post-TBARS steaks, vacuum packaged, and frozen at -20ºC for subsequent analysis. Lipid oxidation was evaluated by TBARS using the modified method of Buege and Aust (1978). A 10 g sample was placed in a blender (model 51BL31, Waring Products, Inc., Torrington, CT) and homogenized with 30 ml of cold deionized water. The mixture was transferred to a disposable tube and centrifuged for 10 min at 3000 rpm. Two ml of supernatant was pulled from the tube and placed in disposable glass tube with 4 ml of thiobarbituric acid/trichloroacetic acid (TBA/TCA) and 100 μL of butylated hydroxyanisol (BHA). Tubes were vortexed and then incubated in a boiling water bath for 15 min, followed by 10 min in a cold water bath. After cooling, samples were centrifuged for 10 min at 3000 rpm. The absorbance was read at 531 nm. A standard curve was generated for each day of analysis using 1,1,3,3-tetra-ethoxypropane (TEP). Lipid oxidation was measured in duplicate for each steak, and the average absorbance reading was used for each sample. Results were expressed as mg of malonaldehyde per kg of sample.

Statistical Analysis

Data were analyzed using the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC). The analysis of variance model for carcass data, WBS, lipid oxidation, and sensory traits included diet as the fixed effect and sire and animal (sire) as the random effects. The analysis of variance model for color attributes were analyzed using a repeated measures model with time as the repeated measure, animal (sire) as the subject, and diet as the fixed effect. Harvest age was included in all models as a covariate. The least

squares means were separated using a pairwise t-test when the model displayed a treatment effect ($\alpha = 0.05$).

RESULTS AND DISCUSSION

Results of carcass characteristics are presented in Table 4.1. Concentrate-fed heifers tended to produce heavier HCW ($P = 0.077$). Mandell et al. (1998) reported heavier HCW of grain-fed steers when harvested at a similar fat thickness to forage-fed steers ($P < 0.01$), and Realini et al., (2004) also found carcasses from concentrate-finished steers were heavier than pasture-finished steers ($P < 0.05$). Carcasses from heifers finished on concentrate in the current study had greater ($P = 0.003$) FAT, a higher ($P < 0.001$) percentage KPH, a higher ($P = 0.011$) USDA calculated YG, and a higher ($P < 0.001$) visual marbling score than forage-finished heifers. Longissimus muscle area was similar ($P > 0.05$) between finishing diets. The absence of a significant difference for LMA agrees with a past study (Mandell et al., 1998) in which forage finishing did not decrease LMA in relation to concentrate finishing when time on feed differed between diets; however, Realini et al. (2004) reported larger LMA in carcasses of concentrate-finished steers compared to pasture-finished steers. The reduced fat thickness of the forage-finished carcasses in the present study is in alignment with the results of previous studies (Schroeder et al., 1980 and Realini et al, 2004). The reduced YG of forage-finished heifers aligns with the increase in cutability of forage-fed animals reported by Schroeder et al. (1980). Schroeder et al. (1980) also reported higher marbling scores for carcasses from grain-fed cattle, which supports the results from the current study.

Results of WBS and sensory traits can be found in Table 4.2. Longissimus muscle steaks from concentrate-finished heifers had lower ($P = 0.003$) WBS values and

higher ($P < 0.001$) sensory tenderness ratings for IT, OT, and CT than steaks from forage-finished heifers. One possible explanation may involve increased fat deposition and the prevention of cold-shortening in concentrate-fed cattle. Similar results for tenderness were produced in a previous study (Schroeder et al., 1980). In contrast, Faucitano et al. (2004) found no differences in WBS values due to diet and actually showed grain-feeding resulted in decreased sensory panel tenderness scores. French et al. (2001) also reported no difference between diets for WBS or any sensory traits.

There was no difference ($P > 0.05$) between diets for initial or sustained juiciness. Steaks from concentrate-finished heifers had higher BF intensity ($P < 0.001$), lower GCF intensity ($P < 0.001$), and higher PFF intensity ($P = 0.011$) than steaks from forage-finished heifers. There was no difference ($P > 0.05$) between diets for LMF intensity. The inferior beef flavor of forage-fed beef agrees with the lower flavor scores found by Schroeder et al. (1980). Also supporting the current study, Mandell et al. (1998) reported slightly more beef flavor and less off-flavor in grain-fed vs. forage-fed beef. The increased beef flavor intensity of concentrate-fed beef may be related to the elevated marbling levels of concentrate-fed heifers.

Results of lipid oxidation are displayed in Table 4.2. Initial TBARS were higher ($P = 0.051$) in steaks obtained from concentrate-finished heifers when compared to grass-finished heifers; however, TBARS were not statistically different ($P > 0.05$) between diets following 7 d in retail display. Increasing the PUFA content due to forage feeding can increase the susceptibility to lipid oxidation; however, the vitamin E antioxidant found in forage-based diets can offset the proxidative properties of PUFA, thus reducing lipid oxidation. O'Sullivan et al. (2003) demonstrated that lipid oxidation was higher in

concentrate-fed animals compared to animals with various levels of forage inclusion in their diet. This difference was observed initially and throughout retail display. Similarly, Realini et al. (2004) reported steaks from pasture-fed animals had lower initial TBARS values than steaks from concentrate-fed animals, with this advantage being maintained throughout retail display. These results contradict the findings of Yang et al. (2002) who found that pasture feeding increased lipid oxidation of aged beef compared to grain-fed beef supplemented with vitamin E.

Generally, diet did not have an effect on instrumental or subjective color (Table 4.3). Instrumentally, L* values were higher ($P < 0.001$) for steaks from concentrate-fed heifers than from forage-fed heifers. All measures of subjective color, as well as a* and b* values were not significantly different ($P > 0.05$) between diets. Although not statistically different, Figure 4.1 demonstrates the change in muscle color scores throughout retail display. The extent of decline in color scores appears to be greater in concentrate-fed beef than forage-fed beef, as scores for concentrate-fed beef are numerically higher initially, but lower than forage-fed beef by the end of display. Figure 4.2 demonstrates the change in surface discoloration scores throughout retail display. A similar trend to muscle color scores can be seen in overall appearance scores (Figure 4.3). The means for L* values throughout retail display are depicted in Figure 4.4. Concentrate-fed beef produced higher L* values than forage-fed beef at each reading throughout display, except at 132 h because all instrumental readings were omitted from analysis for concentrate-fed steaks at this time. Values did not align with readings from surrounding time intervals and were consequently omitted. Means for a* values and b*

values during retail display are shown in Figure 4.5 and Figure 4.6, respectively. Average values for both traits decreased over time, regardless of finishing diet.

Schroeder et al. (1980) reported grain-fed beef was initially brighter and resisted discoloration longer than forage-fed beef, which partially supports the results of the current study. Although muscle color scores were not statistically different, concentrate-fed steaks were initially rated numerically brighter than forage-fed steaks; however, after 84 h of retail display, concentrate-fed steaks appear to discolor more rapidly than forage-fed steaks (Figure 4.2). The results of current study also contradict the findings of Yang et al. (2002) who reported lower a* values in meat from pasture-fed cattle compared to grain-fed beef with or without vitamin E supplementation. However, O'Sullivan et al. (2003) did not find significant differences in color due to diet, which supports the current findings, with the exception of L* values.

CONCLUSION

Finishing diet seems to have a significant effect on carcass characteristics, especially those related to fat deposition. Generally, diet did not have an effect on instrumental or subjective color. Forage-finished cattle are often older than their concentrate-finished counterparts, which can partially explain differences observed in palatability traits in this study. Even after accounting for harvest age, concentrate-fed steaks were rated more tender by panelists and required less force to shear than forage-fed steaks. Moreover, concentrate-fed steaks were rated higher for beef flavor intensity and lower for grassy/cowy flavor than forage-fed steaks. Since consumers in the U.S. have grown so accustomed to the flavor of grain-fed beef, the flavor profile obtained from grass-fed product is often too much to overcome. Although incorporating forages

into beef finishing diets can be beneficial from a human nutritional standpoint, there are still several hurdles to overcome in relation to beef palatability, especially tenderness and flavor.

Table 4.1. Effects of cattle finishing diet on carcass characteristics.

	Concentrate		Forage		
Trait	Mean	SE	Mean	SE	*P*-value
N	97		58		
Hot carcass weight, kg	337.33	9.04	296.99	14.72	0.0773
Fat thickness, cm	1.86	0.13	0.87	0.22	0.0028
LM area, cm^2	84.92	2.21	77.97	3.60	0.2164
KPH, %	2.14	0.09	1.35	0.14	0.0004
USDA calculated YG	3.38	0.18	2.25	0.29	0.0113
Marbling score[1]	59.65	2.67	27.55	4.34	0.0001

[1]10 = practically devoid, 20 = traces, 30 = slight, 40 = small, 50 = modest, 60 = moderate, 70 = slightly abundant, and 80 = moderately abundant.

Table 4.2. Effects of cattle finishing diet on Warner-Bratzler Shear (WBS) force, lipid oxidation, and sensory traits.

	Concentrate		Forage		
Trait	Mean	SE	Mean	SE	*P*-value
N	97		58		
WBS, kg	3.67	0.18	5.05	0.29	0.0031
TBARS[1]					
d 0[2]	0.14	0.01	0.10	0.01	0.0510
d 7[2]	0.12	0.01	0.13	0.02	0.6761
Sensory					
Initial juiciness[3]	5.74	0.12	5.50	0.20	0.4261
Sustained juiciness[3]	5.12	0.11	5.00	0.18	0.6837
Initial tenderness[3]	6.28	0.16	4.29	0.26	0.0001
Overall tenderness[3]	6.12	0.17	3.95	0.28	0.0001
Connective tissue[4]	5.95	0.17	3.76	0.28	0.0001
Beef flavor[5]	2.46	0.07	1.86	0.11	0.0005
Grassy/Cowy flavor[5]	1.13	0.07	2.06	0.11	0.0001
Painty/Fishy flavor[5]	1.32	0.05	0.99	0.08	0.0110
Livery/Metallic flavor[5]	1.05	0.03	1.12	0.05	0.3949

[1]Expressed as mg of malonaldehyde per kg of sample.
[2]Expressed as days in simulated retail display.
[3]1 = extremely dry, extremely tough; 8 = extremely juicy, extremely tender.
[4]1 = abundant; 8 = none.
[5]1 = not detectable; 3 = strong.

Table 4.3. Effects of cattle finishing diet on instrumental and subjective color.

	Concentrate		Forage		
Trait	Mean	SE	Mean	SE	*P*-value
N	97		58		
Instrumental color					
L*[1]	38.36	0.58	32.25	0.88	0.0001
a*[2]	19.52	0.77	22.15	1.17	0.1659
b*[3]	18.70	0.41	18.34	0.62	0.7163
Subjective color					
Muscle color[4]	4.11	0.15	3.91	0.24	0.5931
Surface discoloration[5]	2.66	0.20	2.31	0.33	0.4963
Overall appearance[6]	4.23	0.17	4.19	0.27	0.9403

[1]L* (brightness, 0 = black and 100 = white).
[2]a* (redness/greenness, positive values = red and negative values = green).
[3]b* (yellowness/blueness, positive values = yellow and negative values = blue).
[4]Muscle color (1 = extremely dark red, 8 = extremely bright cherry red).
[5]Surface discoloration (1 = no discoloration, 7 = total discoloration).
[6]Overall appearance (1 = extremely undesirable, 8 = extremely desirable).

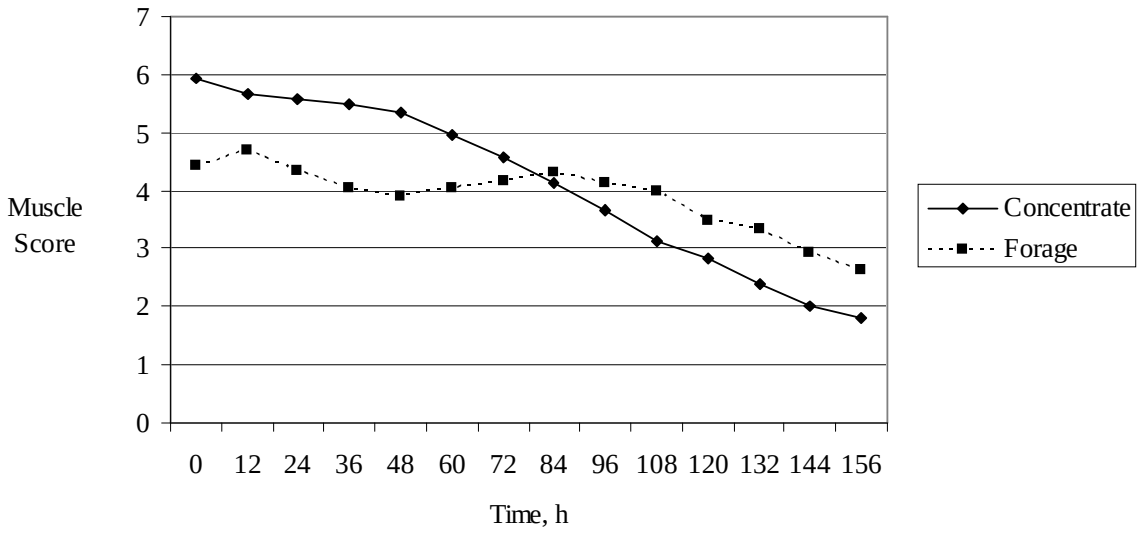

Figure 4.1. Muscle color score LS means (pooled SEM = 0.25) for beef LM steaks from heifers finished on concentrate- (n = 97) or forage-based (n = 58) diets. Muscle color was characterized on an 8-point scale (1 = extremely dark red, and 8 = extremely bright cherry red). There was no overall treatment effect of diet on muscle color scores ($P >$ 0.05).

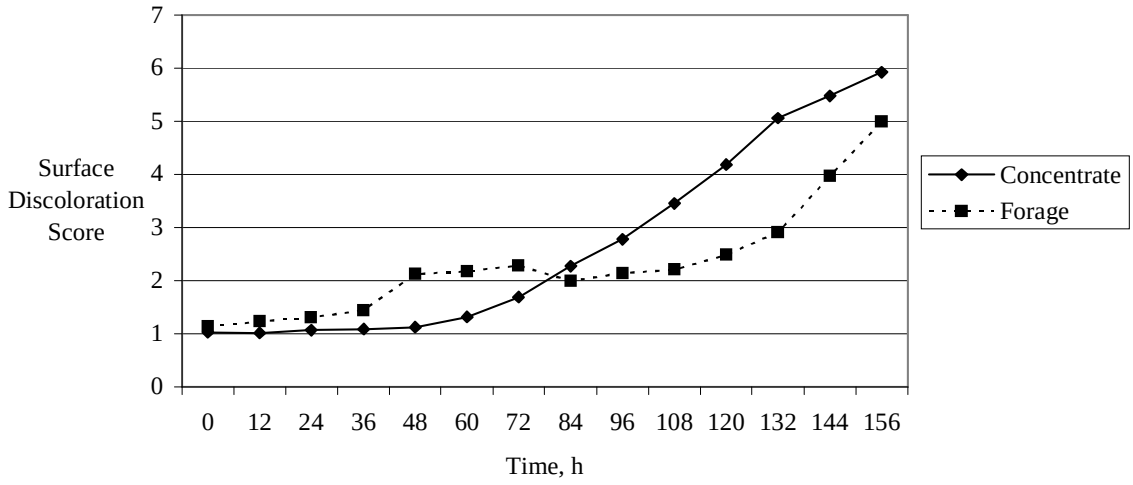

Figure 4.2. Surface discoloration score LS means (pooled SEM = 0.33) for beef LM steaks from heifers finished on concentrate- (n = 97) or forage-based (n = 58) diets. Scores for surface discoloration were assigned based on a 7-point scale [1 = no (0%) discoloration, and 7 = total (100%) discoloration]. There was no overall treatment effect of diet on surface discoloration scores ($P > 0.05$).

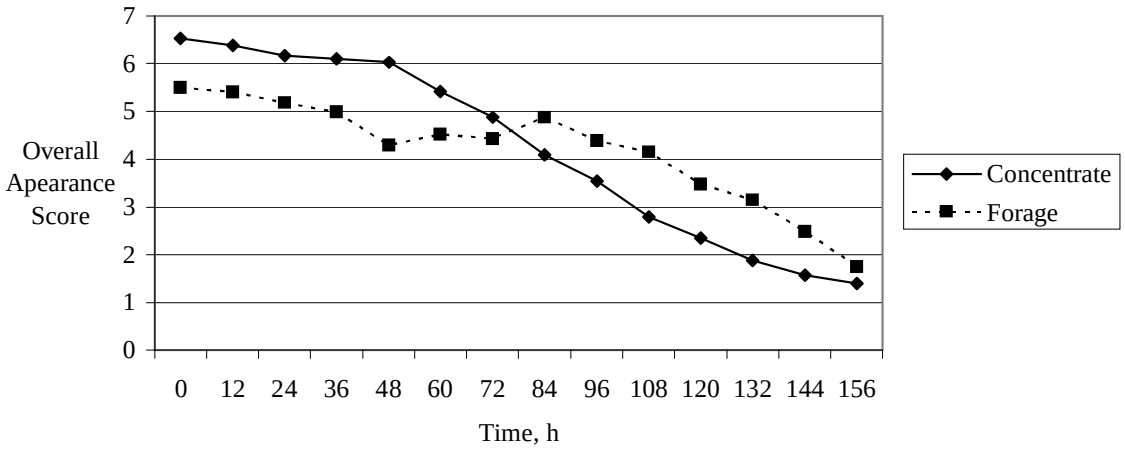

Figure 4.3. Overall appearance score LS means (pooled SEM = 0.29) for beef LM steaks from heifers finished on concentrate- (n = 97) or forage-based (n = 58) diets. Overall appearance was scored on an 8-point scale (1 = extremely undesirable and 8 = extremely desirable). There was no overall treatment effect of diet on overall appearance scores ($P > 0.05$).

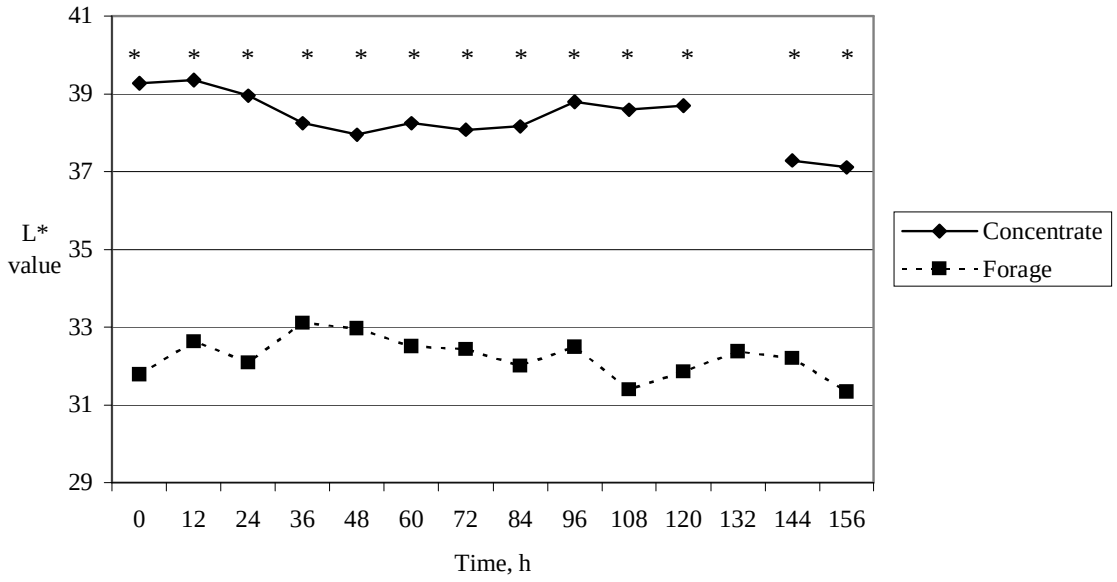

Figure 4.4. L* value LS means (pooled SEM = 0.79) for beef LM steaks from heifers finished on concentrate- (n = 97) or forage-based (n = 58) diets. L* values were used to determine brightness (0 = black and 100 = white). Means with * differ ($P < 0.05$).

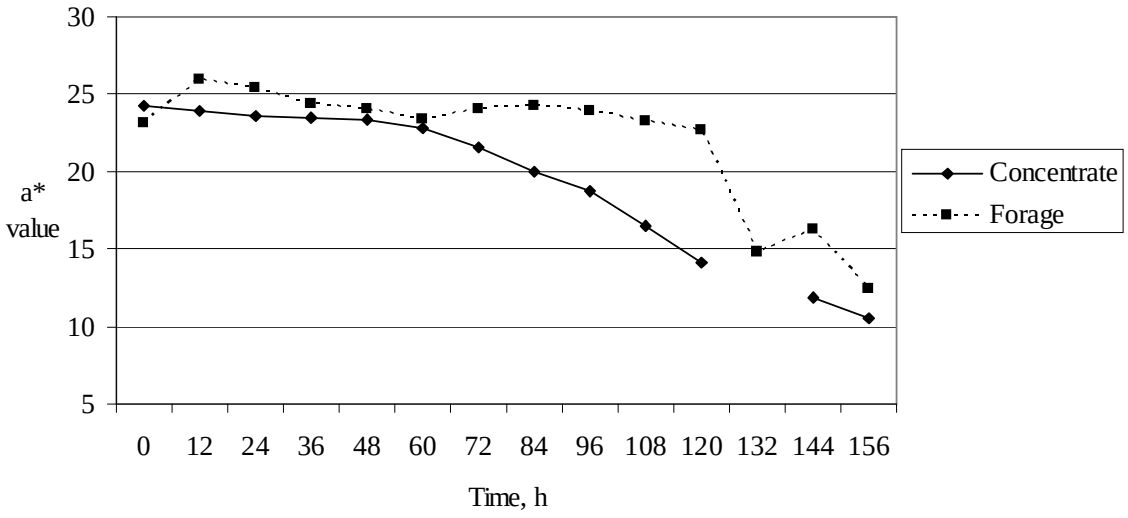

Figure 4.5. a* value LS means (pooled SEM = 1.20) for beef LM steaks from heifers finished on concentrate- (n = 97) or forage-based (n = 58) diets. The a* values were used to evaluate redness/greenness (positive values = red and negative values = green). There was no overall treatment effect of diet on a* values ($P > 0.05$).

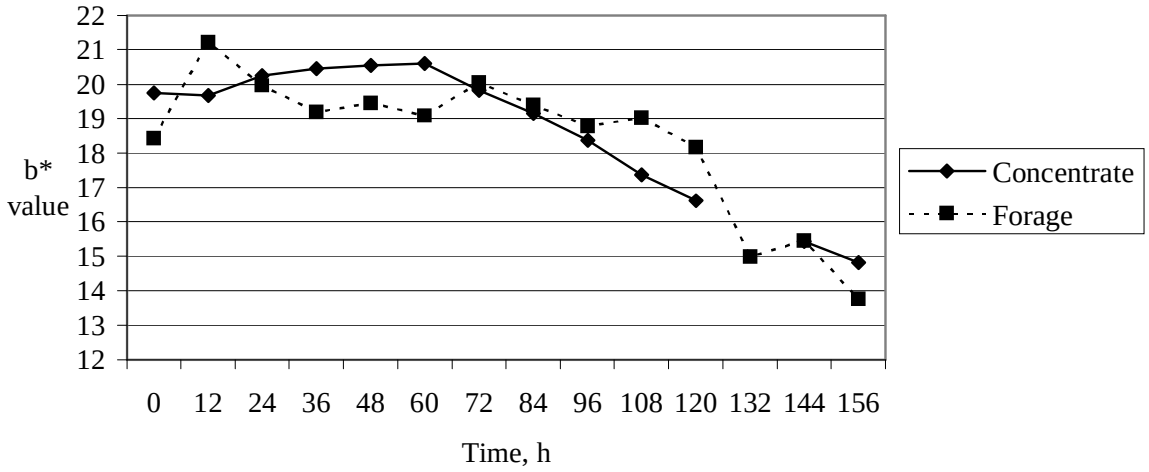

Figure 4.6. b* value LS means (pooled SEM = 0.65) for beef LM steaks from heifers finished on concentrate- (n = 97) or forage-based (n = 58) diets. The b* values were used to assess yellowness/blueness (positive values = yellow and negative values = blue). There was no overall treatment effect of diet on b* values ($P > 0.05$).

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APPENDICES

Appendix A

Oklahoma State University Institutional Review Board

Date:	Thursday, April 10, 2008
IRB Application No	AG0817
Proposal Title:	Utilization of Natural Genomic Variation to Enhance Nutritional and health Values of Beef
Reviewed and Processed as:	Exempt

Status Recommended by Reviewer(s): Approved Protocol Expires: 4/9/2009

Principal Investigator(s):

Deborah VanOverbeke
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Stillwater, OK 74078

Andrea Garmyn
113 Animal Science
Stillwater, OK 74078

Gretchen Hilton
104A Animal Science
Stillwater, OK 74078

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

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

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

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

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

Sincerely,

Sue C. Kennison

Sue C. Kennison, Chair
Institutional Review Board

Appendix B

Thin Layer Chromatography for separation of TG and PL

1. Using a total lipid extract in 10 mL of chloroform, originating from 2 grams of fresh sample, pipette 1000 uL into a 12 x 125 mm labeled tube.
2. Evaporate the solvent with gentle heat and a stream of nitrogen gas.
3. For separation into phospholipids and triacylglycerol:
    a. Put approximately 100 mL of hexane:ethyl acetate (3:1) into two TLC tanks and cover
    b. Add a piece of filter paper, behind glass slide, to tank to aid in separation
4. For separation into phospholipid, monoacylglycerol, diacylglycerol, triacylglycerol, and free fatty acids:
    a. Put approximately 100 mL of hexane:ethyl acetate (80:20; v:v) into two TLC tanks and cover
    b. Add a piece of filter paper, behind glass slide, to tank to aid in separation
5. While samples are drying, purge source vials with nitrogen gas and return them to the cold room.
6. Using a "T" square, score 9 lanes in the plate (Silica gel G, Analtech, 20 x 20 cm, catalog # 01011).
7. Resuspend the dry test tube lipid from step #1 in 2-3 drops of chloroform, roll tube to suspend lipid, and apply to a lane on the TLC plate.
8. Purge a TLC tank with nitrogen gas and place the plate in the chamber for development. When the solvent is about 1 cm from the top of the plate, remove it and place it in another dry chamber with a stream of nitrogen gas flowing through it.
9. When the plate is dry, work quickly to scrape all of the spots into a labeled tube by using a razor and waxine paper. Do each spot, one at a time into separate tubes.
10. To derivatize the samples, add 2 mL of methanol:benzene (4:1, v:v).
    a. Stop point if needed: purge with nitrogen.
    b. To continue: add 200 uL of acetyl chloride per tube while vortexing.
11. Purge tubes with nitrogen gas and cap tightly.
12. Heat the samples in a dry bath for 1 hour at 100^{o}C.
13. Remove the samples from heat and allow to cool until they reach room temperature.
14. Add 5 mL of 6% K2CO3 (w:v) and then add 1 mL of hexane to all tubes.
15. Vortex the samples for 15 seconds and centrifuge at low speed for 10 minutes to achieve phase separation.
16. Aspirate at least 0.5 mL of hexane (upper phase) into GC vials for analysis. It is crucial that NO AQUEOUS phase is transferred.
17. Purge the GC vials with nitrogen gas and store in freezer until analysis.

VITA

Andrea Jo Garmyn

Candidate for the Degree of

Doctor of Philosophy

Dissertation: RELATIONSHIPS BETWEEN NUTRIENT COMPONENTS OF LONGISSIMUS MUSCLE AND BEEF PALATABILITY TRAITS AND INFLUENCE OF FINISHING DIET ON BEEF QUALITY

Major Field: Food Science

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Education: Graduated from Hicksville High School, Hicksville, OH in June 2000. Received a Bachelor of Science in Agriculture, majoring in Animal Sciences from The Ohio State University, Columbus, OH in December, 2004. Completed the requirements for the Master of Science with a major in Animal Breeding and Genetics at Kansas State University, Manhattan, KS in August, 2007. Completed the requirements for the Doctor of Philosophy in Food Science at Oklahoma State University, Stillwater, OK in December, 2009.

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Title of Study: RELATIONSHIPS BETWEEN NUTRIENT COMPONENTS OF LONGISSIMUS MUSCLE AND BEEF PALATABILITY TRAITS AND INFLUENCE OF FINISHING DIET ON BEEF QUALITY

Pages in Study: 71 Candidate for the Degree of Doctor of Philosophy

Major Field: Food Science

Scope and Method of Study: The first objective was to determine the influence of beef longissimus nutrient components on beef palatability traits by utilizing cattle from two related herds. Longissimus muscle (LM) samples were obtained and fabricated into steaks for trained sensory panel, Warner-Bratzler Shear force (WBS), thiobarbituric acid reactive substances (TBARS), and healthfulness (fatty acid and mineral composition) analysis. The goal of the second study was to assess the influence of finishing diet on carcass traits, beef palatability, and color stability of LM of Angus heifers. Steaks were fabricated similarly to the correlation study with the addition of a steak for simulated retail display.

Findings and Conclusions: Specific mineral concentrations did not demonstrate strong correlations with WBS, sensory traits, or TBARS, and significant correlations were not consistent between the two cattle populations. Linoleic acid (C18:2) was the only fatty acid significantly correlated ($P < 0.05$) with WBS in California samples, but C18:1, C18:2, C18:3n-3, C18:3n-6, and MUFA were significantly correlated with WBS in Iowa samples. There were weak correlations ($P < 0.05$) with C16:0, C18:0, C18:1, C18:2, SFA, and MUFA in Iowa samples for initial and sustained juiciness. Specific fatty acids that demonstrated significant correlations with sensory tenderness ratings were generally weak and inconsistent between the two populations. Beef flavor was positively correlated ($P < 0.05$) with C14:0, C16:0, C18:1, and MUFA in both populations. Painty/fishy flavor was negatively correlated ($P < 0.05$) with C18:2 and PUFA in California samples, but was positively correlated ($P < 0.05$) with the same traits in Iowa samples. There were no consistent relationships between lipid composition and livery/metallic flavor between the two populations.

Carcasses from grain-fed heifers were fatter at the 12th rib and internally and had higher numerical yield grades and marbling scores than forage-finished heifers ($P < 0.05$). Steaks from grain-fed heifers had lower WBS values, higher tenderness ratings, higher beef and painty/fishy flavor, and lower grassy/cowy flavor than forage-fed beef ($P < 0.05$). Diet did not affect color, except grain-fed heifers had steaks with higher ($P < 0.05$) L* values than steaks from forage-fed heifers.

ADVISER'S APPROVAL: Dr. Gretchen G. Hilton