Marinating Effects on the Sensory Characteristics of Grain- and Forage-finished Beef

by

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Abstract

Beef inside round roasts (n = 144) were cut from rounds obtained from both forage-finished cattle (n = 72) and grain-finished cattle (n = 72). Roasts were portioned to weigh approximately 0.45-0.68 kg. Each roast was then randomly assigned one of the following treatments: control, pumped-no cure and pumped-cured. Additionally, roasts were assigned a serving temperature (hot and cold) and aging treatments (0- and 28-d post cooking). Separate brines were mixed for each lot (n = 3) and two roasts per cattle diet, injection, serving temperature, and aging period combination were pumped. Roasts that were pumped were injected to approximately 30% of green weight with the appropriate brine solution. Sensory characteristics were evaluated by a trained 6-8 person panel. Additionally, surface and interior color; shear force; lipid oxidation; and pumped, tumbled and cook loss weight percentages were all evaluated. Cured and uncured roasts had greater scores ($P < 0.05$) for soy, salty, grassy and sweet flavor intensity. Additionally, tenderness values were greater ($P < 0.05$) for both cured and uncured roasts as compared to control roasts from both groups. Results show that the greatest intensity ($P < 0.05$) of grassy flavor was found in forage control roasts aged 28 d. Forage control roasts aged 0 d as well as uncured forage roasts, both 0 and 28 d aged, had similar scores ($P > 0.05$). Forage roasts that were cured had the lowest ($P < 0.05$) grassy flavor scores for both 0 and 28 d aging periods. Cured roasts served cold had lowest ($P <0.05$) grassy flavor compared to all control treatments. Control roasts aged 28 d and served hot had greater ($P < 0.05$) grassy scores than any cured or uncured roasts. Forage-fed beef was perceived as more juicy ($P < 0.05$) than grain-finished beef. Cured roasts had the lowest warmed over flavor scores ($P < 0.05$) regardless of serving temperature or diet. Animals fed a forage-based diet yielded roasts with greater ($P < 0.05$) shear force values. Control roasts had greater ($P < 0.05$) shear force values than both roasts that were cured and pumped with no cure. Surface and interior a* values were greater ($P < 0.05$) for forage-finished animals as well as all cured roasts. In conclusion, data suggests that injecting brines into forage-fed beef significantly improves tenderness and multiple flavor characteristics.

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Review of Literature

Alternative Production Systems

For many years, researchers have addressed the differences among traditional grain-finishing management systems and alternative finishing programs, such as a forage-based system. Conventionally, grains are a significant element in beef cattle production systems within the United States; however in the wake of recent increases in grain and fuel prices, many beef producers have begun to evaluate finishing systems that are primarily based on the consumption of available forage rather than concentrate diets.

Starting in the 1970's, researchers began predicting that the beef industry would reduce grain usage in response to increased foreign demand for grains as well as steadily rising fuel prices. In response to this decrease, research on the proper utilization of all readily available energy sources, specifically forages, became necessary (Hodgson, 1977). Similarly, Clanton (1977) stated that due to consistently increasing grain prices, beef producers within the United States would be forced to find an alternative management system that depended on forages. While initial costs may be present to start a forage-finishing system, research shows that finishing animals in a forage-based system is an economically sound decision. In a comparison of high energy finishing systems with forage-finishing systems, researchers found that animals finished on forage had lower production costs (Huffman and Boucher, 1987).

In addition to rising grain and fuel prices, another factor that is playing a major role in increasing interest in forage-finished beef is consumer trends. Feedlots in the United States are under a constant, watchful eye by environmental agencies around the world. Additionally, consumers are becoming more conscious of their diet decisions and the implied consequences of those decisions on their health. As a result of this awareness, consumers are demanding a healthier product. These consumers specifically want beef with reduced saturated fatty acids (SFA), increased omega-3 polyunsaturated fatty acids (PUFA) and increased conjugated linoleic acid (CLA). The key to increasing the above mentioned beneficial fatty acids is controlling the animal’s diet (Scollan et al., 2006). In a study conducted by Faucitano et al., (2008) researchers concluded that the requests of today’s health conscious consumer could be fulfilled by producing cattle in a forage-based system.

Forage Finishing in Southeastern United States

Traditionally, the southeastern region of the United States is not known as an area that finishes market cattle. Due to geographical location and available resources, the southeastern United States is typically a region that is dominated by cow-calf production rather than finishing systems. However, mild winter climates, consistent rainfall and soil systems in this area allow producers to excel in growing forages year-round (Allen et al., 1996). This has led many producers in the southeastern United States to address the possibilities of implementing forage-based finishing systems for both economic and sustainability purposes.

There are two distinct seasons in the southeast that produce various grasses for finishing beef cattle—a cool season and a warm season. Typically, there are various cool season grasses readily available, such as rye, ryegrass, wheat-ryegrass, cereal grain-ryegrass-clover and ryegrass-clover. Frequently used summer annuals include sorgham-sudangrass, millet, alyceclover, and cowpeas. Additionally, summer perennials such as bahiagrass, bermudagrass, and bermudagrass hybrids such as Coastal, Alicia and Brazos are also commonly utilized (Bagley et al., 1988). Research shows that on average, warm season grasses are generally more abundant than most cool season grasses (Wilson, 1984). However, cool season grasses are characteristically of higher nutritional quality (Bagley et al., 1988).

While the warmer climates in the southeastern region are desirable for maintaining forage systems year-round, the possible negative effects on the animal must be taken into consideration. The southeast is known to have consistently high temperatures and high humidity levels in the summer months. High temperatures often have a negative impact on animals in a finishing system such as reduced weight gain and less feed intake (Bagley, 1975).

Carcass Characteristics

While some of the positive aspects of implementing a forage-based production system are evident, a perceived negative characteristic among producers and researchers alike is the effect of the management system on carcass quality. Forage-fed and grain-fed beef often differ in carcass quality, back-fat thickness and carcass weight (Bidner et al., 1986; McMillin et al., 1984).

Beef quality is a major economic concern for beef cattle producers. Marbling, or intramuscular fat deposition and carcass maturity are key components in the determination of beef quality; typically, a carcass exhibiting higher levels of marbling and lower maturity values is considered of higher quality on the USDA grading scale. While early studies found that consumers prefer a steak with higher levels of marbling (Dunsing, 1959), other research shows that while consumers do consider marbling to be an important factor in selection, they actually prefer lower levels of marbling (Forbes et al., 1974; Killinger et al., 2004) as marbling leads to the perception of higher fat content.

Some studies have found that higher degrees of marbling are linked to enhancement in flavor, juiciness and tenderness (Smith et al., 1985; May et al., 1992). Jeremiah (1996) found that although the correlations were slight, animals having a minimum back fat thickness of 9.0 mm along with a “small” degree of marbling yield a consumer acceptability of approximately 90%. However, other researchers have found that there is little to no correlation between marbling and palatability characteristics (Miller et al., 1987; Reagan et al., 1981).

Similarly, researchers have found differing conclusions on the impact of forage-based diets on beef quality. In addition to lower marbling scores, cattle fed forage-based diets have been shown to have less subcutaneous fat as well when compared to cattle finished on high energy diets (McMillin et al., 1982; 1984). Bidner and others (1986) found cattle finished on a high-energy system averaged 9.4 mm of back fat compared to 5.9 mm in forage-finished animals. Additionally grain-finished cattle had a score of 7.8 (slight) for marbling while forage-fed cattle had an average score of 5.2 (traces) which correlated to the grain-fed animals having higher quality grades as well.

However, in opposing studies, researchers compared animals fed ryegrass/white clover and ad-libitum high energy rations and found no differences in levels of intramuscular fat content (Davies, 1977). In a study conducted evaluating steers fed either ryegrass, grain or a combination of the two, researchers found that while animals fed ryegrass or a ryegrass combination diet did exhibit higher bone and lean maturity scores, there were no differences found among marbling scores or total USDA quality grading values (Kerth et al., 2006).

Researchers have attempted to find a way to manage cattle in order to improve marbling scores in forage-fed animals. It has been considered that marbling may be improved in forage-finished animals by choosing specific types of cattle. Research shows that smaller-framed cattle commonly exhibit higher degrees of marbling when compared to larger-framed, slower maturing cattle (Marshall, 1994). Additionally, researchers have evaluated various dietary supplements to increase marbling and speed finishing times. Baublits et al. (2004) found that supplementing forage-based diets with soy hulls significantly increased both marbling scores and quality grades.

Subcutaneous fat, commonly referred to as back-fat, is an important factor commonly used today in assessing a market animals' readiness for slaughter. Typically, as grain levels in rations increase, the amount of back-fat present at slaughter increases as well (Berthiaume et al., 2006). Generally, animals fed forage-based diets have lower amounts of subcutaneous fat when compared to animals fed high energy, grain based diets (Kerth et al., 2006; Bennett et al., 1995; McMillin et al., 1984). Similarly, Bowling et al. (1978) found that while forage-fed steers had higher percentages of both lean and bone mass, they had less fat than steers finished on either grain or a forage-grain combination. Researchers have speculated that these lower levels of back-fat are correlated with cooling times (Bruce et al., 2004). As subcutaneous fat decreases, it is understood that a carcass will chill more quickly. When a shorter postmortem chilling time combines with a higher ultimate muscle pH the carcass will often possess a darker colored lean as opposed to traditional grain-finished beef (Bruce et al., 2004).

Another noteworthy characteristic that is often considerably impacted by a forage-based diet is carcass weight. Animals finished on forage-based diets often have lower carcass weights when compared to animals fed grain for the same number of days on feed (McMillin et al., 1984; Bennett et al., 1995; Mandell et al., 1998; Tatum et al., 1988). When feeding animals to a similar market weight, Bowling et al. (1978) found steers fed a high-grain diet reached market weight much sooner, approximately 180 d, than animals finished on forage.

However, recent research has shown that supplementation with various products at the end of the finishing period can increase hot carcass weights. A recent study evaluated supplementing forage-based diets with soy hulls. This supplementation can significantly increase both live and hot carcass weights for animals fed on a forage-based system (Baublits et al., 2004). Bretschneider et al. (2008) found that feeding specific levels of antibiotic growth promoters in combination with estradiol implants significantly increased average daily gain in animals grazing high quality pastures. Similarly, Berthiaume and others (2006) conducted a feeding trial evaluating finishing systems using both grass silage and various levels of growth promotants and grain feed. Results showed that both growth promotants and the addition or either soybean meal or barley could increase hot carcass weights. Additionally, results showed that due to both lower hot carcass weights and quality grades, non-implanted cattle finished on forage would require a 16% premium in order to be economically comparable to traditionally finished cattle. However, the use of growth promoters could possibly be an issue as the typical consumer found within the forage-finished beef niche market desires a “natural” product.

Color

Researchers and consumers alike agree that meat color is one of the most reliable and accessible indicators of meat quality (Savell et al., 1989; Forbes et al., 1974). Consumers consistently maintain that color is an important factor in their decision to purchase a meat product; typically consumers see discoloration as an indicator of spoilage (Grunnert, 1997). Annually, this perception of product spoilage leads to more than $1 billion in lost revenue (Smith et al., 2000). As a result, meat color has become one of the most researched topics in the meat science industry for both beef and pork.

According to Mancini and Hunt (2005) one of the most important ante-mortem factors affecting meat color stability is the animal’s diet; animal diets affect muscle color through several factors including stored glycogen levels, amount of fat deposition, and rate of chilling or even total antioxidant accumulation.

Vestergaard et al. (2000) found that cattle fed forage-based diets in controlled amounts exhibited a darker muscle color than cattle fed ad libitum grain; however, Baublits et al. (2004) reported that cattle fed forage-based diets displayed improved muscle coloring when supplemented with soy hulls. The dark muscle coloring in forage-fed cattle is due to less subcutaneous fat which results in faster postmortem chilling. When a shorter postmortem chilling time combines with a higher ultimate muscle pH the carcass will often possess a darker colored lean as opposed to traditional grain-finished beef (Bruce et al., 2004). However, in a study conducted by Poulson et al. (2004), results showed that meat from forage-finished animals retained redness better than meat from animals finished on high-grain diet. Poulson speculated that this could possibly be attributed to the forage-finished cattle having 300% higher levels of α-tocopherol when compared to grain-finished cattle. However, forage-fed cattle often exhibit a less desirable fat color as opposed to traditionally finished beef cattle (Kerth et al., 2006). Typically, grain-finished cattle display white fat while cattle fed forages or diets high in roughage rations exhibit a slightly yellowed fat color (Abdullah et al., 1979; Kerth et al., 2006).

Tenderness

Tenderness is often recognized as the most important and most complex quality indicator in beef (Miller et al., 1995). Additionally, research indicates that consumers are often willing to pay a premium for a cut that is guaranteed as tender (Miller et al., 2001; Boleman et al., 1997). Generally, tenderness is a variable characteristic that is perceived as resistance to tooth pressure. Tenderness is dependent upon multiple characteristics including connective tissue, sarcomere length, post-mortem protein degradation and background effects such as marbling.

All of the factors that affect tenderness are altered through various management practices, including animal diet, age, genetics, stress, growth promotants and physical activity. With all of these factors in mind, multiple studies comparing tenderness in forage- and grain- finished cattle have been conducted and yield contradictory results. Several studies identify tenderness in forage-finished cattle as an issue of concern (Reverte et al., 2003; Kerth et al., 2006; Brewer and Calkins, 2003).

Producing animals on forage-based finishing systems results in higher Warner-Bratzler shear force values as well as lower sensory scores related to tenderness (Kerth et al., 2006; Mitchell et al., 1991). Many speculations have been made on the negative correlation between forage-finished beef and tenderness. Some research hypothesizes that longer finishing times and animal age at slaughter has a negative impact on meat tenderness (Brewer and Calkins, 2003). Brewer and Calkins (2003) also cited cold shortening as another potential cause of decreased tenderness in forage-fed beef. This cold shortening was attributed to lower amounts of subcutaneous fat.

Contradictory research shows that cattle can be fed on a forage-based finishing system without having a negative impact on tenderness (French et al., 2000; 2001; Poulson et al., 2004). A study conducted by Mandell and others (1998) found that there were no significant differences in firmness, tenderness or time spent chewing when comparing steaks from both forage-based and high grain diets. One study reveals similar initial shear force values in forage- and grain-fed steers and lower shear force values for forage-fed steers at 7 and 14 day aging periods (Realini et al., 2004). Another project reported similar results, as steers finished on an all-forage diet had superior tenderness ratings compared to steers finished on an all-grain diet (Oltjen et al., 1971).

Ante-mortem controls may be utilized in order to improve tenderness in forage-fed animals. Supplementing a forage-based diet with low levels of grain feeds produces a more acceptable and tender product than a solely forage-based diet. In a study evaluating meat quality in steers fed autumn grass, grass silage or grain diets, results showed that supplementing a grass-based diet with low grain levels produced more tender meat at 2 days postmortem (French et al., 2000); however, in a comparable study, low levels of corn supplementation for steers finished on ryegrass based diets, yielded no significant improvements in initial or sustained tenderness (Roberts et al., 2009).

Several post mortem practices have been evaluated for tenderness improvement in forage-fed beef as well. One study found that forage-fed animals could exhibit improved tenderness when subjected to combinations of dry aging, pelvic suspension, blade tenderization and electrical stimulation (Smith et al., 1979). Kerth and others (2007) speculated that while steers finished on rye-forage based diets did have less desirable tenderness scores, a simple aging treatment or electrical stimulation could be sufficient to improve tenderness and make them comparable to animals fed grain-based diets based solely on the aspect of tenderness.

Flavor

Some research indicates that the overall consumer acceptability of beef is determined by flavor (Theunissen et al., 1979). While tenderness and flavor are often very comparable in consumer rankings, Goodson (2002) found that flavor in clod steaks had the highest simple correlation to overall likeness ratings in the product, when compared to all other sensory attributes. Due to the obvious importance of beef flavor as it relates to consumer acceptance, it is imperative to understand the attributes that affect flavor.

A substantial number of compounds give meat its typical flavor and aromatic characteristics (Calkins and Hodgen, 2007). These compounds include various sulfurous compounds, carbonyls, aldehydes, alcohols, hydrocarbons, pyridines, ketones and many others. Each compound contributes to a specific flavor. For example, 1, 3-Bis (1, 1-dimethylethyl) benzene is often associated with a "cooked beef flavor", heptanal generates an "oily, rancid unpleasant" flavor and hexanal is generally related to a "fatty-green, grassy" flavor (Calkins and Hodgen, 2007).

Another important factor contributing to meat flavor is lipid content and oxidation (Ladikos and Lougovois, 1990). Lipid oxidation is dependent upon the types of fatty acids present as well as their composition and the presence of pro-oxidants. Reactions between polyunsaturated fatty acid and oxygen cause the formation of by-products such as aldehydes, furans and ketones. These by-products contribute to the off-flavors associated with rancidity and spoilage (Ladikos and Lougovois, 1990).

When evaluating the relationship between animal diet and flavor, forage- and grain-finishing systems are often compared. In early comparisons, sensory panelists found that forage-fed beef was not necessarily lacking in flavor, rather that it possessed a distinct off-flavor (Brown et al., 1979).

Much of the research comparing flavor profiles in forage- and grain-finished beef is conflicting. In trained and household panels, participants gave lower flavor scores for range-finished beef when compared to grain-fed cattle (Medeiros et al., 1987). In a comparison of steers fed corn, pellet or forage-based diets for 90 days, steers finished on a high energy system possessed more desirable and intense beef flavors (Melton, 1982). However, in a more recent study, results showed that when animals were blocked by growth-rate and fed forage- or grain-based diets, there were no significant differences found in quality or flavor (French et al., 2001)

Additionally, forage types have an effect on flavor profile. Rape and vetch pastures produce a distinct, undesirable off-flavor in lambs when compared to ryegrass and white clover (Park and Thomas, 1973). In addition, lambs grazed on white clover pastures exhibited a more intense characteristic lamb flavor than lambs finished on ryegrass (Spurway, 1972). However, in a more recent study, researchers found that meat from cattle given feed additives to sustain an invariable growth rate and finished on autumn grass, grass, and silage possessed no differences in flavor (French et al., 2000).

Juiciness

Romans et al. (2001) identified the relationship evident between juiciness and tenderness as a positive correlation; as juiciness in meat increases, so does the perception of tenderness. While juiciness is not always identified by research as one of the most significant sensory traits in meat, studies show that consumers generally base their decisions to purchase a meat product on a combination of tenderness, juiciness and flavor (Savell et al., 1987).

While research comparing juiciness among forage- and grain-fed beef is limited, most studies find very few differences among cattle from the two management practices. Mandell et al. (1998) found that there were no significant differences in initial or sustained tenderness as well as initial or sustained juiciness in cattle fed both forage- and grain-based diets. However, Sapp et al. (1999) found forage-finished cattle to have lower juiciness scores when compared to grain-finished cattle.

Consumer Acceptability

Characteristically, the United States beef industry produces and markets beef from grain-fed cattle. This has resulted in Americans developing a taste for grain-finished beef as opposed to beef from alternative finishing systems such as forage-based finishing diets. However, recently due to consumer demands, forage-finished beef is becoming a marketable niche product for beef producers. Consumers have recently begun requesting products that are healthier, leaner and “natural”; forage-fed beef has become the answer to many of these consumers (Faucitano et al., 2008).

Schroeder et al. (1980) conducted a survey consisting of an eight-member trained sensory panel comparing palatability differences between forage- and grain-finished beef. Through these surveys, researchers found that steaks from cattle on all forage-based diets had “limited retail acceptability” and scored lower for all sensory attributes. However, consumer trends are often not appropriately represented by trained panels. Often, consumer opinions are affected by peripheral factors such as price and nutrition facts. There are numerous studies addressing consumer trends and preferences in the forage fed beef market. In multiple studies, researchers have concluded that while the greater part of American consumers prefers traditional grain-fed beef, there is a sector of shoppers who favor forage-fed beef (Cox et al., 2006; Kerth et al., 2006; Sitz et al., 2005).

Kerth et al., (2006) found that 22.22% of consumers preferred forage-fed beef to grain-fed in a blind taste test. In a similar study conducted in Alabama, Tennessee and Kentucky by Cox et al. (2006), 34.1% of retail consumers and 52.0% of take-home consumers preferred forage-finished steaks over grain-finished steaks. Additionally, consumers that preferred forage-finished beef over grain-finished beef were willing to pay a premium for it. Sitz et al. (2005) found that consumers who did prefer forage-fed steaks were willing to pay a premium for such products; in fact, on average consumers were willing to pay $1.38/0.45 kg more. In a comparable study, Umberger et al., (2002) found that 23% of consumers surveyed not only preferred forage-fed beef, but were willing to pay a premium of $1.36 more per pound. However, consumers for the large part are not willing to accept forage finished beef. While Sitz et al., (2005) found that some consumers were willing to pay a premium for forage-fed beef, the majority of people surveyed preferred domestic grain-fed beef.

Nutritional Quality/Fatty Acid Composition

In response to the aforementioned consumer demands, beef producers in the United States are evaluating ways to improve the nutritional quality within beef products. Specifically, producers and researchers alike are looking for ways to reduce saturated fatty acids (SFA) and increase omega-3 polyunsaturated fatty acids (PUFA) as well as conjugated linoleic acid (CLA). The health implications of consuming CLA are numerous and the list continues to grow at a rapid rate. A recent review by Pariza (2004) found that there were benefits in areas including weight-loss, immune system enhancement and improvement in blood lipids. Researchers have found that one of the easiest ways to manipulate these attributes is to control the animals' diet (Scollan et al., 2006). Recently, research has concluded that the requests of today's health-conscious consumer can be fulfilled by producing cattle in a forage-based system (Faucitano et al., 2008).

Consumers are searching for protein sources that also provide them with high levels of omega-3 polyunsaturated fatty acids (Krutulyte et al., 2008). These desirable fatty acids are commonly found in fish; however there have recently been concerns among consumers related to consuming large amounts of fish due to chemical contaminants, such as mercury (Domingo et al., 2007). This and other circumstances have led consumers to look to alternative sources of omega-3 fatty acids. Research shows that as forage levels increase in an animal's diet, levels of polyunsaturated fatty acids increases (Wood et al., 2003).

While it is understood that beef naturally contains omega-3 fatty acids, animal diet can often increase these levels substantially. Poulson et al. (2004) found that simply feeding forages instead of a grain-based diet raised the concentration of $C_{18:2}$ *cis*-9, *trans*-11isomer of CLA in beef in some cases as much as 466%. Similarly, Warren et al. (2008) compared animals fed either grain- or grass silage-based diets. As a result of grass silage being rich in α-linolenic acid, feeding this diet increased this particular fatty acid by a factor of three in meat when compared to grain-finished animals. In contrast, the level of linoleic acid was higher in animals fed the grain diet. However, due to the significant increase in *n*-3 series fatty acids, there was a beneficially low ratio of *n*-6: *n*-3 fatty acids.

Lipid Stability and Shelf-Life

Lipid oxidation has become a very important topic as it relates to food quality and deterioration (Campo et al., 2005). When lipid oxidation occurs, volatile secondary oxidation products, such as hexanal, are formed (Skibsted et al., 1998). These products are what causes the actual “rancid” off-flavors found in meat (Grey and Pearson, 1994).

Lipid stability and its relation to shelf life stability are elements often evaluated in forage-fed vs. grain-fed beef. Contradictory information is often presented when evaluating lipid stability in forage-fed beef. Often, animals fed forage-based diets are considered to have a more stable lipid system as a result of higher levels of α-tocopherol and other naturally occurring antioxidants; however, the products are also considered to be more susceptible to undergoing lipid oxidation due to a significantly increased level of polyunsaturated fatty acids (Yang et al., 2001).

Warren et al. (2007) found animals fed a forage-based diet exhibited lower levels of lipid oxidation on days 4 and 7 of retail display as well as increased color stability. Researchers felt this difference could be due to higher plasma and muscle levels of α-tocopherol. However, in a study where both forage- and grain-fed animals had α-tocopherol supplementation, results showed that grain-finished beef with α-tocopherol supplementation had more lipid stability than both the control and supplemented forage-fed beef (Yang et al., 2001).

While the presence of natural antioxidants such as α-tocopherol has obvious benefits in color and lipid stability, there have been some adverse effects identified in consumer acceptability (Robbins et al., 2003). However, Reverte et al. (2003) found that the addition of other compounds, such as beef flavoring, in addition to anti-oxidants can mask the negative flavors associated with antioxidants without impeding its benefits.

Natural Curing

While the research on forage-fed beef is abundant, there is limited information on further processing of forage-finished beef. For centuries, people have been curing meat in order to preserve products (Aberle et al., 2001). Eventually, it became understood that curing also improved other aspects of meat such as color, flavor and texture.

Originally, meat curing was achieved by using a combination of salt with sodium- or potassium-nitrate (Sebranek, 1979). By the late 1800's, researchers found that nitrate was reduced to nitrite by bacteria, and that nitrite was the actual component responsible for curing (Sebranek and Bacus, 2007). Further research established safe and effective use levels as authorized by the USDA in 1925 (Sebranek and Bacus, 2007). The use of nitrite in meat products has been shown to reduce microbial growth, preserve meat flavor and prevent the formation of warmed-over flavors (Aberle et al., 2001).

While the benefits of nitrite in meat processing are evident, potential safety and health issues are of significant concern for regulatory agencies as well as processors and consumers. The carcinogenic potential of nitrate and nitrite has been an issue of debate in the meat industry since the 1970’s (Sebranek and Bacus, 2007). However, in 2006 the International Agency for Research on Cancer, found that the ingestion of nitrite and nitrate under certain conditions was “probably carcinogenic to humans” (Coughlin, 2006).

Due to consumer health concerns related to this issue, processors have developed more label-friendly “natural” curing methods. Some of the most popular ingredients used for natural curing are vegetable sources or spices. Vegetables such as celery and beets have been shown to have nitrate concentrations as high as 2800 ppm (National Academy of Sciences, 1981). Sebranek and Bacus (2007) found that celery juice or celery powder was well suited as a natural curing agent for meat processing as there was very little vegetable pigment and a very mild natural flavoring. Some studies have found that curing by using celery juice powders combined with starter cultures, for nitrate reduction, very closely mimics traditional curing methods (Sindelar et al., 2007a; Sindelar et al., 2007b); however, the shelf-life of these products is often shorter than the shelf-life of traditional, nitrite-cured products (Bacus, 2006.) While these processing techniques and labeling options have “enjoyed wide-spread market acceptance,” they are often considered perplexing and even deceptive to consumers (Sebranek and Bacus, 2007).

Research Objectives

As a result of varying issues, including consumer health demands, environmental issues and steadily increasing grain and fuel prices, producers are evaluating finishing beef in a healthier and more economical manner. Finishing cattle within forage-based systems appears to be a potential practical solution to a number of these concerns. However, research in the area of further processing and value-added products in forage-finished beef is exceptionally limited.

In recent years, the beef industry has struggled to improve product development in the area of value-added products. Therefore, it is not only important to evaluate potential alternative finishing systems, but to also evaluate how products from these animals will perform when further processed. This project not only compares and contrasts the specific processing characteristics of forage- and grain-fed beef, but also evaluates the different flavor profiles and sensory attributes of each and how further processing affects these traits.

Additionally, natural curing methods will be used in order to maintain a more “natural” product that would be more marketable to the niche forage-fed beef industry.

Materials and Methods

Experimental Design

Beef inside round roasts (n = 144) were cut from rounds obtained from both forage-finished cattle (n = 72) and grain-finished cattle (n = 72). Forage-fed cattle were finished on a combination of ryegrass and oats. Grain-finished inside rounds were received from National Beef Packing Company, LLC (Kansas City, MO). All roasts were fresh prior to processing. Roasts were portioned to weigh approximately 0.45-0.68 kg. Each roast was then randomly assigned one of the following treatments: control, pumped-no cure and pumped-cured. Additionally, roasts were assigned a serving temperature (hot and cold) and aging treatments (0- and 28-d post cooking).

Separate brines were mixed for each lot (n = 3) and two roasts per treatment, serving temperature, and aging period combination were pumped. Prior to treatment, each roast was weighed in order to obtain an exact green weight. Control roasts were passed through a multi-needle injector (model PI 9-52 Pickle Injector; Gunther Maschinenbau GmbH, Dieburg, Germany) three times with no brine injected in order to maintain a consistent treatment for all products. Roasts that were pumped were injected to approximately 30% of green weight with the appropriate brine solution (Table 1).

After roasts were pumped, each sample was reweighed and pumped weights were recorded. Next, each lot of roasts were tagged and placed into small-batch vacuum tumblers (model Ideal (LU25) Vacuum Tumbler; Lumar Ideal II Inc., Montreal, QC Canada) for 30 minutes with like treatments. After tumbling, roasts were vacuum packaged in cook-in bags (model CNR 530; Cryovac Food Packaging Systems, Greenville, SC) and cooked in a smokehouse (model Grand Prize™ 3 Smokehouse; KOCH, Kansas City, MO) on a steam cycle (Appendix A).

After roasts were cooked to an internal temperature of 65°C, they were placed into a chill cooler and cooled to 2°C. The 0-d roasts were immediately frozen at -20°C after cooling while 28-d roasts remained in the cooler another 4 wk and were then frozen at -20°C until evaluation.

Color Evaluation

Commission International de l'Eclairage (CIE) lean L* (muscle lightness), a* (muscle redness) and b* (muscle yellowness) values were evaluated using a Hunter Miniscan XE Plus (model MSXP-4500C; Hunter Laboratories, Reston, VA). Illuminant setting D65 at 10° and a 3.5-cm aperture were utilized.

Roasts were randomly selected and thawed for 24 h at 3 ± 1°C prior to color measurement. Color scores were taken immediately before sensory evaluation. Samples served warm had color scores taken after heating. Two readings each were taken from the external surface and the internal, sliced surface area. Each set of measurements were then averaged to obtain a representative measure of color for both the external and internal area of the sample. Hue angle (wavelength of light radiation of red, yellow, green, blue and purple) was calculated by using an equation as described by Hunt (1980) and Clydesdale (1991).

Sensory Evaluation

Prior to sensory evaluation, panelists conducted round-table evaluations on test roasts in order to establish flavor profiles. After potential off-flavors were identified, various compounds were used in order to train panelists on these specific flavors (Appendix B). After panelists were trained on particular off-flavors as well as tenderness, juiciness, and texture, test roasts were again evaluated.

A trained sensory panel (6-8 members) evaluated each roast. Panelists were trained to evaluate tenderness, juiciness and texture as well as off-flavors. Roasts were randomly selected and thawed for 24 h at 3 ± 1°C. Prior to serving, roasts that were to be served hot were heated for 6 minutes in their bags on HIGH using a microwave (model MW8999RD; Emerson Radio Corporation, Parsippany, NJ); cold samples were sliced immediately after thawing. The roasts were then sliced to approximately 0.4 cm in thickness on a 130 watt meat slicer with a 19 cm circular blade (model FS03; LEM Products, Harrison, OH). Hot roasts were wrapped in aluminum foil and placed into warming ovens at approximately 65°C until served to panelists. Cold roasts were wrapped in aluminum foil and stored in the refrigerator until served.

Panelists were seated in individual, partitioned booths with 250 Lx of red incandescent light. Prior to each session, a warm-up sample was served, scored and discussed. Next, panelists were served three to six samples at each sensory session. Each panelist was given two samples from each roast. Samples were evaluated for beefy, salty, warmed-over, soy, sweet, grassy and other off flavors including livery, bloody, sour, metallic, nutty and weedy. Additionally, panelists were asked to score overall tenderness, texture and juiciness.

Panelists were asked to mark their score on an anchored line with the left side representing extremely bland flavor, extremely tough, extremely cohesive and extremely dry, and the right side representing intense flavor, extremely tender, extremely mealy and extremely juicy respectively (Appendix C). Panelists were instructed to expectorate the sample and cleanse their palate by taking a bite of an un-salted saltine cracker and drinking water after each sample was evaluated, and scores recorded. After sensory preparation, remaining portions of each sample were vacuum packaged, immediately refrozen and stored at -20°C for both shear-force and lipid oxidation analysis.

Shear Evaluation

Tenderness was evaluated by using the Warner-Bratzler shear force method according to AMSA (1995) guidelines. Frozen roasts were removed from the freezer and allowed to thaw for 24 h at 3 ± 1°C. All roasts were sampled immediately after thawing. No samples were reheated prior to evaluation. Roasts were removed from the vacuum package and cored. Six cores, 1.3 cm in diameter, were taken from each sample parallel to the muscle fiber. Each core was then individually sheared across the middle using a Dynamometer Scale (model 1955; G. R. Electric Manufacturing, Manhattan, KS). The peak forces from the six cores were averaged for statistical analysis purposes.

Lipid Oxidation Evaluation

Lipid oxidation was assessed using a thiobarbituric acid (TBA) reactive substance assay as modified from Wang and others (2002; Appendix D).

Statistical Analysis

Color, sensory, shear force and lipid oxidation evaluations were all analyzed as a factorial arrangement of a completely randomized design using the general linear model procedure. Animal diet (forage or grain), serving temperature (cold or hot), aging (0d or 28d) and processing treatment (control, uncured or cured) served as fixed effects. Significant ($P < 0.05$) main effect, two-, three- and four-way interaction least squares means were separated by Fisher's Protected LSD using the LSMeans statement and PDIFF option of SAS (SAS Inst. Inc., Cary, NC).

Results

The least squares means for both surface and interior color, as affected by diet and serving temperature is shown in Table 2. Both surface and interior L* values were higher ($P < 0.05$) for animals fed grain-based diets compared to forage-based diets as well as roasts that were served cold compared to those served hot. While there were no influences ($P > 0.05$) on surface a* from either feed or serving temperature, interior a* scores were lower ($P < 0.05$) for both grain-finished roasts compared to forage-fed roasts as well as roasts served hot compared to those served cold. Surface b* values were lower ($P < 0.05$) for roasts from forage-fed roasts that were served hot; however, roasts from grain-fed animals served hot had lower ($P < 0.05$) surface b* values when compared to forage-fed roasts served cold. Forage-fed roasts served cold had surface b* values similar ($P > 0.05$) to grain-fed roasts at both serving temperatures. Similarly, interior b* values were lower ($P < 0.05$) for roasts served hot than roasts served cold while diet had no effects ($P > 0.05$).

When comparing least squares means for color values as influenced by both feed and processing treatment (Table 3), surface L* values were higher ($P < 0.05$) for cured roasts when compared to both the controls and roasts with no cure. Surface a* values for cured roasts were higher ($P < 0.05$) in both feed groups; however, while the forage and grain control roasts had similar ($P > 0.05$) surface a* values, the forage control roast was higher ($P < 0.05$) than both the uncured forage and grain roasts.

Grain control roasts surface a* values were similar ($P > 0.05$) to uncured forage roasts. However, uncured forage roasts had higher ($P < 0.05$) surface a* values when compared to uncured grain roasts, which had the lowest ($P < 0.05$) surface a* values. Control roasts had higher ($P < 0.05$) surface b* values when compared to uncured roasts which had higher ($P < 0.05$) surface b* values than cured roasts. Interior L* scores were higher ($P < 0.05$) for roasts from grain-fed animals as well as roasts that were either cured or pumped with no cure. Interior a* values were highest ($P < 0.05$) for cured roasts; uncured roasts exhibited the lowest ($P < 0.05$) interior a* scores. Processing treatment did alter b* values as control had the highest numbers ($P < 0.05$), followed by uncured and cured, respectively.

Least squares means for color values as affected by both aging period and processing treatment are evaluated in Table 4. Interior L* values were affected by aging treatment as 28 d roasts had higher scores ($P < 0.05$) than 0 day roasts. Sliced a* values were highest ($P < 0.05$) for 0 d cured roasts. The 28 d a* values were greater ($P < 0.05$) for cured roasts than 0 d control which were higher ($P < 0.05$) than both 28 d control and 28 d uncured. Uncured roasts that underwent a 0 d aging period had the lowest ($P < 0.05$) interior a* values.

While surface L* and interior a* values had no interaction, serving temperature affected them similarly as both scores were lower ($P < 0.05$, Table 5) for roasts served hot. Surface and interior a* values were higher ($P < 0.05$) for cured roasts served both hot and cold than control roasts served cold. However, control roasts served cold had higher ($P < 0.05$) surface and interior a* values than controls served hot as well as uncured roasts of both serving temperatures.

Tenderness differences among roasts exposed to different aging periods as well as different serving temperatures are evaluated in Table 6. Results show that roasts aged 28 d and served hot had higher ($P < 0.05$) shear force scores than 0 d roasts served hot as well as both 0 and 28 d roasts served cold. Additionally, Table 7 shows tenderness differences among roasts that underwent different diets as well as different processing treatments. Animals fed a forage-based diet yielded roasts with higher ($P < 0.05$) shear force values. Control roasts had higher ($P < 0.05$) shear force values than both roasts that were cured and pumped with no cure.

Lipid oxidation of roasts according to the thiobarbituric acid reactive substance assay as it is affected by both serving temperature and processing treatment is shown in Table 8. Control roasts served hot had similar ($P > 0.05$) values when compared to uncured roasts served either hot or cold. Uncured roasts from both serving temperatures were comparable ($P > 0.05$) to cured roasts at both serving temperatures. Additionally, uncured hot roasts were similar ($P > 0.05$) to both serving temperatures of cured roasts as well as control roasts served cold.

The differences in pumped weight, tumbled weight and cook-loss percentages among forage- and grain-finished roasts subjected to each type of processing treatment is shown in Table 9. Pumped percentage was highest ($P < 0.05$) for both uncured and cured forage-finished roasts. Additionally, pumped and uncured grain roasts had higher ($P < 0.05$) pump percentages than cured grain roasts. Similarly, both cured and uncured forage roasts had highest ($P < 0.05$) values for tumbled percentages; however there were no differences ($P > 0.05$) between the cured and uncured grain roasts. As expected both pumped weight and tumbled weight percentages were lowest ($P < 0.05$)

in both forage and grain controls as they were not injected with brine solutions. Diet and processing treatment had no effect ($P > 0.05$) on cook-loss percentages.

While there were no differences ($P > 0.05$, Table 10) in pumped or tumbled percentages, cook loss percentage was highest ($P < 0.05$) for roasts aged 0 d and served hot followed by roasts aged 28 d and served hot. There was no difference ($P > 0.05$) between 0 and 28 d roasts served cold.

The comparison of least square means for all sensory attributes as affected by diet, serving temperature and aging period is shown in Table 11. When comparing differences in diet, forage-fed beef had higher scores ($P < 0.05$) for salt, soy and forage flavor intensities. Additionally, forage-fed beef had higher juiciness scores ($P < 0.05$) than grain-finished beef. Serving temperature affected tenderness as roasts served cold were more tender ($P < 0.05$) than roasts served hot. Additionally, cold roasts had higher intensity scores ($P < 0.05$) for “other” off flavors as opposed to roasts served hot. Aging period affected tenderness as roasts stored 28 d had more desirable tenderness rankings ($P < 0.05$) compared to 0 d roasts. An interaction of temperature and age altered juiciness as both 0 and 28 d roasts served cold had the highest ($P < 0.05$) scores. Juiciness scores in 28 d roasts served hot were higher ($P < 0.05$) than scores for 0 d roasts served hot. Beefy flavor in grain-fed roasts were not affected ($P > 0.05$) by serving temperature or aging time, but within forage-fed roasts, 0 d roasts served hot had lower ($P < 0.05$) scores than all others.

Sensory evaluation scores as affected by feed, processing treatment and serving temperature are shown in Table 12. Treatment alone affected soy, salty, grassy and sweet flavor intensity as cured and uncured products understandably had higher scores

($P < 0.05$) for both flavors. Additionally, tenderness values were higher ($P < 0.05$) for both cured and uncured roasts as compared to control roasts from both groups. A treatment by temperature interaction affected beef flavor as control roasts served hot had lower ($P < 0.05$) beef intensity flavor scores compared to all other treatments served both hot and cold. Uncured roasts served cold were rated less cohesive ($P < 0.05$) than control roasts served hot which were more mealy ($P < 0.05$) than control roasts served cold. Cured roasts served hot and cold as well as uncured roasts served hot were all similar ($P > 0.05$) in texture scores. Uncured roasts served cold were similar ($P > 0.05$) in texture scores to uncured roasts served hot as well as cured roasts served cold, but less cohesive than cured roasts served hot ($P < 0.05$). A treatment and temperature interaction affected juiciness as well, as cured roasts served cold and uncured roasts served cold had higher ($P < 0.05$) juiciness scores than cured and uncured roasts served hot. Additionally, cured and uncured roasts served hot as well as control roasts served cold had higher ($P < 0.05$) juiciness scores than control roasts served hot. Cured roasts had the lowest warmed over flavor scores ($P < 0.05$) regardless of serving temperature or diet. Additionally, grain-fed controls served hot and uncured were equally as low as all cured ($P > 0.05$). While forage-fed controls served cold had lower ($P < 0.05$) WOF scores than forage-fed controls served hot, grain-fed served cold had higher ($P < 0.05$) WOF scores than grain-fed served hot.

Grassy off flavor scores were affected by feed, processing treatment and aging period (Figure 1). Results show that the highest intensity ($P < 0.05$) of grassy flavor is found in forage control roasts aged 28 d. Forage control roasts aged 0 d as well as uncured forage roasts, both 0 and 28 d aged, had similar scores ($P > 0.05$). Forage roasts that were cured had the lowest (*P* < 0.05) grassy flavor scores for both 0 and 28 d aging periods.

Cured roasts served cold had lowest (P <0.05, Figure 2) grassy flavor compared to all control treatments. Control roasts aged 28 d and served hot had higher (*P* < 0.05) grassy scores than any cured or uncured roasts.

Discussion

Starting in the 1970's, researchers began predicting that the beef industry would reduce grain usage in response to increased foreign demands for grains as well as steadily rising fuel prices. In response to this decrease, research on the proper utilization of all readily available energy sources, specifically forages became necessary (Hodgson, 1977).

The aforementioned issues have led researchers to evaluate the sensory and nutrient differences in forage- and grain-fed beef over the last thirty years. However, there has been no published research on the comparison of forage- and grain-finished beef subjected to further processing treatments. Due to this information, this study proves extremely useful as the sensory attributes of both forage- and grain-fed roasts are evaluated after further processing.

Color evaluations for this study were difficult to compare as color values were only obtained in cooked products and the research on cooked forage-fed beef color is nonexistent. However, results agreed with Vestergaard et al. (2000) in finding forage-finished beef had substantially darker muscle coloring when compared to grain-fed cattle. Additionally, as expected, all cured products had higher surface and interior a* values when compared to both the control and uncured roasts.

Tenderness was found to be significantly less desirable according to Warner Bratzler shear force values in forage-fed beef as opposed to grain-fed beef which agrees with Reverte et al. (2003), Kerth et al. (2006), Brewer and Calkins (2003) and Mitchell et al. (1991). However, roasts that underwent a 28 d aging period and were served warm had significantly lower shear force values as compared to all other treatments; injecting products with either a curing solution or a brine solution with no cure improved tenderness across all feeds, aging periods and serving temperatures. This research shows that by injecting forage-fed roasts with brine solutions and allowing longer aging periods, tenderness in forage-fed beef may be improved. However, in contradiction to Kerth et al. (2006) and Mitchell et al. (1991) sensory panelists found no differences in tenderness based on feed treatment.

Lipid oxidation, evaluated using the thiobarbituric acid reactive substance (TBARS) assay, showed no differences in oxidation due to feed treatment. However, serving roasts cold and the addition of either a cured or uncured brine reduced oxidation significantly for both forage- and grain-fed roasts aged both 0 and 28 d.

Contradictory to Sapp et al. (1999), results of this study found that sensory panelists found forage-fed roasts to be juicier when compared to grain-finished roasts. In addition to higher sensory panel scores for juiciness, pumped weight and tumbled weight percentages were higher for forage-fed beef than grain-fed beef. Higher sensory panel scores for juiciness and more pump absorption are likely due to the higher pH in forage-fed beef (Bruce et al., 2004).

When evaluating sensory panel scores for forage-finished beef, results for beef flavor intensity agreed with Melton et al. (1983) as beef flavor was significantly higher for grain-finished cattle as opposed to forage-fed cattle. While panelists were still able to identify grass flavors in all forage-fed roasts, regardless of the treatment, scores for saltiness and soy were higher for forage-fed beef. These higher values could possibly be attributed to the higher pumped and tumbled weight percentages for forage-fed beef.

Processing treatment showed a significant effect on the ability of panelists to detect grassy off-flavors. Curing a product significantly decreased the capacity of panelists to detect grassy flavors. Additionally, aging a control roast for 28 d substantially increased the presence of grass flavors compared to 0 d roasts according to panelists.

In conclusion, while research in forage-fed beef is expanding, the sector of further processed forage-fed beef has remained untouched and still encompasses many unknowns. Further research is needed to evaluate the significant effects further processing has on sensory traits of forage-fed beef as compared to typical grain-finished beef.

Implications

Data suggests that injecting brines into forage-fed beef significantly improves tenderness and multiple flavor characteristics. Additionally, forage-fed beef is capable of retaining higher percentages of injections. Injecting forage-fed beef with brines, with or without natural curing ingredients, improves the eating quality and shelf life of inside round roasts. Future research is needed to evaluate the capacity of further processing to affect the sensory characteristics of forage-finished beef. More trained sensory panel work as well as consumer evaluations would prove extremely useful.

Tables and Figures

Table 1. List of ingredients for cured and uncured brine and percentage of ingredients in final product

Product	Ingredient	Percentage in Final Product
Uncured	Water	18.93
	Refined Sea Salt; Morton Salt, Chicago, Illinois	1.20
	Evaporated Cane Juice Crystals; Florida Crystals Sugars, South Bay, Florida	0.60
	Isolate Soy Protein, Supro-248; Solae Company, St. Louis, Missouri	1.60
	PURE-DENT® Food Corn Starch, B-747; Grain Processing Corporation, Muscatine, Iowa	0.75
Cured	Water	18.73
	Refined Sea Salt; Morton Salt, Chicago, Illinois	1.20
	Evaporated Cane Juice Crystals; Florida Crystals Sugars, South Bay, Florida	0.60
	Isolate Soy Protein, Supro-248; Solae Company, St. Louis, Missouri	1.60
	PURE-DENT® Food Corn Starch, B-747; Grain Processing Corporation, Muscatine, Iowa	0.75
	Veg Stable™ 504, Celery Powder; Florida Food Products, Inc., Eustis, Florida	0.192
	Veg Stable™ 515, Cherry Powder; Florida Food Products, Inc., Eustis, Florida	0.154

Table 2. Least Squares Means ± SEM of surface and interior L*, a* and b* for diet and serving temperature

	Treatment							
	Grass[a]		Grain[a]		SEM	P > F		
	Served Hot	Served Cold	Served Hot	Served Cold		Diet	Serving* Temperature	Diet* Temperature
Surface L*	36.11	45.91	41.06	48.66	0.688	<0.0001	<0.0001	0.116
Surface a*	8.86	9.73	9.04	8.94	0.247	0.211	0.128	0.057
Surface b*	13.05[d]	15.10[bc]	14.58[c]	15.39[b]	0.212	<0.0001	<0.0001	0.005
Interior L*	48.89	51.79	52.56	54.13	0.585	<0.0001	0.0004	0.259
Interior a*	10.73	12.37	9.80	10.65	0.377	0.001	0.002	0.302
Interior b*	14.74	15.54	14.91	15.27	0.220	0.822	0.011	0.337

[a] Grass- animals finished on forage-based diet, Grain-animals finished on traditional grain-based diet

[b,c,d] Means in a row with different superscripts differ (P<0.05).

Table 3. Least Squares Means ± SEM of surface and interior L*, a* and b* for diet and processing treatment

	Treatment						SEM	P > F	
	Grass[a]			Grain[a]					
	Control[b]	Cured[b]	No Cure[b]	Control	Cured	No Cure		Treatment	Treatment*Diet
Surface L*	39.08^{y}	45.21^{x}	38.75^{y}	41.55^{y}	48.89^{x}	44.15^{y}	0.842	<0.0001	0.997
Surface a*	9.15^{d}	10.58^{c}	8.18^{e}	8.56^{de}	11.14^{c}	7.27^{f}	0.302	<0.0001	0.048
Surface b*	15.34^{x}	13.21^{z}	13.67^{y}	16.05^{x}	13.87^{z}	15.03^{y}	0.260	<0.0001	0.321
Interior L*	49.33^{y}	50.39^{x}	51.31^{x}	51.69^{y}	53.79^{x}	54.55^{x}	0.716	0.005	0.732
Interior a*	10.62^{y}	14.83^{x}	9.18^{z}	9.14^{y}	14.15^{x}	7.37^{z}	0.462	<0.0001	0.457
Interior b*	16.70^{x}	12.60^{z}	16.12^{y}	16.86^{x}	12.82^{z}	15.59^{y}	0.269	<0.0001	0.311

[a] Grass- animals finished on forage-based diet, Grain-animals finished on traditional grain-based diet

[b] Processing treatment; Control=no pump, Cured=Pumped with brine and celery powder, No Cure=pumped with brine

^{c,d,e,f} Means in a row with different superscripts differ ($P<0.05$) for Treatment*Feed interaction

^{x,y,z} Means in a row with different superscripts differ ($P<0.05$) for Treatment main effect

Table 4. Least Squares Means ± SEM of surface and interior L*, a* and b* for aging period and processing treatment

	Treatment						SEM	P > F	
	0 d Age			28 d Age					
	Control[a]	Cured[a]	No Cure[a]	Control	Cured	No Cure		Age	Treatment*Age
Surface L*	40.84	46.41	41.57	39.79	47.70	41.33	0.842	0.997	0.377
Surface a*	9.23	11.17	7.74	8.47	10.55	7.71	0.302	0.063	0.447
Surface b*	15.96	13.67	14.15	15.42	13.40	14.55	0.260	0.515	0.183
Interior L*	49.52	51.54	53.62	51.50	52.64	53.24	0.716	0.040	0.629
Interior a*	10.55[c]	14.53[a]	7.62[e]	9.21[d]	14.46[b]	8.94[d]	0.462	0.935	0.022
Interior b*	16.84	12.75	15.75	16.72	12.67	15.95	0.270	0.995	0.812

[a] Processing treatment; Control=no pump, Cured=Pumped with brine and celery powder, No Cure=pumped with brine

[b,c,d,e,] Means in a row with different superscripts differ (P<0.05) for Treatment*Age interaction

Table 5. Least Squares Means ± SEM of surface and interior L*, a* and b* for serving temperature and processing treatment

	Treatment						SEM	P > F	
	Served Cold			Served Hot					
	Control[a]	Cured[a]	No Cure[a]	Control	Cured	No Cure		Serving Temperature	Treatment* Temperature
Surface L*	44.92	51.10	45.85	35.71	43.00	37.05	0.842	< 0.0001	0.803
Surface a*	9.69^{c}	10.56^{b}	7.76^{d}	8.01^{d}	11.16^{b}	7.69^{d}	0.302	0.128	0.002
Surface b*	17.12^{b}	13.56^{de}	15.07^{c}	14.27^{d}	13.53^{e}	13.63^{de}	0.260	< 0.0001	< 0.0001
Interior L*	52.57^{bc}	52.34^{bc}	53.97^{b}	48.44^{d}	51.85^{c}	51.89^{c}	0.716	0.0004	0.048
Interior a*	11.59^{c}	14.17^{b}	8.76^{d}	8.17^{d}	14.81^{b}	7.80^{d}	0.462	0.002	0.0003
Interior b*	17.39	12.70	16.12	16.17	12.71	15.59	0.269	0.0110	0.084

[a] Processing treatment; Control=no pump, Cured=Pumped with brine and celery powder, No Cure=pumped with brine

[b,c,d,e,] Means in a row with different superscripts differ ($P<0.05$) for Processing Treatment*Serving Temperature interaction

Table 6. Least Squares Means ± SEM of Warner Bratzler shear force for serving temperature and aging period

	Treatment				SEM	P > F		
	Served Cold		Served Hot					
	0 d Age	28 d Age	0 d Age	28 d Age		Temperature	Age	Temperature* Age
Kilograms	3.99^{b}	3.92^{b}	3.91^{b}	4.43^{a}	0.145	0.160	0.137	0.047

^{a,b}Means in a row with different superscripts differ ($P<0.05$)

Table 7. Least Squares Means ± SEM of Warner Bratzler shear force for feed and processing treatment

	Diet				Treatment				
	Grass[a]	Grain[a]	SEM	P > F	Control[b]	Pumped-No Cure[b]	Pumped-Cured[b]	SEM	P > F
Kilograms	4.29	3.84	0.103	0.003	4.55[c]	3.83[d]	3.81[d]	0.146	0.0001

[a] Grass- animals finished on forage-based diet, Grain-animals finished on traditional grain-based diet
[b] Processing treatment; Control=no pump, Cured=Pumped with brine and celery powder, No Cure=pumped with brine
[c,d] Means in a row with different superscripts differ (P<0.05)

Table 8. Least Squares Means ± SEM of thiobarbituric acid reactive substance (TBARS) assay for serving temperature and processing treatment

	Treatment						SEM	P > F		
	Served Hot			Served Cold						
	Control[a]	Cured[a]	No Cure[a]	Control	Cured	No Cure		Temperature	Treatment	Temperature * Treatment
mg MDA/ kg wet tissue	1.77[b]	1.10[cd]	1.22[bcd]	0.762[d]	1.01[cd]	1.39[bc]	0.213	0.0806	0.449	0.019

[a] Processing treatment; Control=no pump, Cured=Pumped with brine and celery powder, No Cure=pumped with brine

[b,c,d] Means in a row with different superscripts differ (P<0.05)

Table 9. Least Squares Means ± SEM of pump %, tumble % and cook loss % for feed and processing treatment

	Treatment						SEM	P > F		
	Grass[a]			Grain[a]						
	Control[b]	Cured[b]	No Cure[b]	Control	Cured	No Cure		Diet	Treatment	Diet* Treatment
Pump %	0.088[f]	37.45[c]	37.22[c]	0.16[f]	27.50[e]	30.19[d]	0.008	<0.0001	<0.0001	<0.0001
Tumble %	0.05[e]	30.77[c]	31.76[c]	-0.11[e]	22.66[d]	23.18[d]	0.010	<0.0001	<0.0001	<0.0001
Cook-Loss %	33.25	34.03	34.33	32.27	32.82	33.32	0.010	0.191	0.557	0.993

[a] Grass-animals finished on forage-based diet, Grain-animals finished on traditional grain-based diet

[b] Processing treatment; Control=no pump, Cured=Pumped with brine and celery powder, No Cure=pumped with brine

[c,d,e,f] Means in a row with different superscripts differ (P<0.05)

Table 10. Least Squares Means ± SEM of pump %, tumble % and cook loss % for serving temperature and aging period

	Treatment				SEM	P > F		
	0 d Age		28 d Age					
	Hot	Cold	Hot	Cold		Age	Serving Temperature	Age*Serving Temperature
Pump %	21.7	22.0	22.0	22.7	0.007	0.454	0.524	0.770
Tumble %	17.7	18.0	17.9	18.7	0.008	0.556	0.518	0.796
Cook-Loss %	41.8^{a}	26.5^{c}	37.8^{b}	27.2^{c}	0.008	0.052	<0.0001	0.005

^{a,b,c} Means in a row with different superscripts differ ($P<0.05$)

Table 11. Sensory scores as affected by feed, serving temperature and aging period

	Treatment													
	Grass[a] Served Cold		Grass[a] Served Hot		Grain Served Cold		Grain Served Hot		SEM	P>F				
	0 Day	28 Day	0 Day	28 Day	0 Day	28 Day	0 Day	28 Day		Feed	Serving Temp	Age	Temp * Age	Feed* Temp* Age
Beefy[b]	41.4^{gh}	38.0^{hi}	34.7^{i}	40.9^{gh}	41.2^{gh}	43.2^{g}	43.0^{g}	39.7^{gh}	1.62	0.010	0.246	0.728	0.353	0.002
Salty[b]	29.9	29.1	27.2	25.2	25.5	22.7	24.8	23.3	1.98	0.009	0.252	0.225	0.958	0.682
WOF[b]	19.1^{hi}	19.4^{hi}	28.5^{g}	22.9^{gh}	22.7^{gh}	19.8^{hi}	14.8^{i}	22.2^{h}	2.13	0.091	0.225	0.897	0.459	0.011
Soy[b]	19.5	20.9	22.1	22.2	12.9	17.5	18.9	20.0	2.46	0.032	0.082	0.305	0.498	0.742
Sweet[b]	2.4	6.3	5.9	6.9	5.9	4.9	5.9	6.2	1.11	0.660	0.090	0.184	0.613	0.174
Grass[b]	3.7	5.9	5.4	7.1	3.0	2.4	1.6	2.6	0.99	0.001	0.584	0.135	0.711	0.476
Other[b]	10.9	13.9	6.3	6.3	12.8	12.7	3.3	4.2	2.06	0.446	0.001	0.524	0.738	0.480
Tender[c]	61.8	62.2	49.8	54.5	56.6	60.4	50.5	57.1	2.31	0.568	0.001	0.021	0.277	0.821
Texture[c]	44.5	44.1	40.3	41.6	46.3	43.2	43.8	47.7	2.38	0.125	0.484	0.804	0.211	0.432
Juicy[c]	65.2^{d}	63.1^{d}	42.2^{f}	51.4^{e}	54.5^{d}	54.2^{d}	40.0^{f}	46.5^{e}	2.30	0.002	0.001	0.046	0.008	0.497

[a] Grass-animals finished on forage-based diet, Grain-animals finished on traditional grain-based diet

[b] Flavor scores based on 100 point scale, 0=very bland and 100=very strong

[c] Sensory scores based on 100 point scale, 0=very tough, very cohesive and very dry and 100=very tender, very mealy and very juicy

[d,e ,f] Means in a row with different superscripts differ ($P<0.05$) for Serving Temperature*Aging Period

[g,h,i] Means in a row with different superscripts differ ($P<0.05$) for Feed*Serving Temperature*Aging Period

Table 12. Sensory scores as affected by feed, processing treatment and serving temperature

	Treatment															
	Grass[a]						Grain[a]									
	Control		Cured		Uncured		Control		Cured		Uncured		SEM	P>F		
	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot		Trt	Trt* Temp	Feed* Trt* Temp
Beefy[b]	41.9^{g}	28.3^{h}	38.8^{g}	42.4^{g}	38.4^{g}	42.8^{g}	43.7^{g}	38.3^{g}	40.3^{g}	41.9^{g}	42.3^{g}	43.9^{g}	1.97	0.023	0.001	0.091
Salty[b]	1.7	3.4	40.3	31.4	46.5	44.1	2.0	3.0	35.7	31.8	34.6	37.3	2.43	0.001	0.066	0.634
WOF[b]	22.3^{lmno}	33.1^{k}	11.8^{q}	14.4^{pq}	23.6^{lmn}	29.6^{kl}	27.9^{klm}	18.0^{nopq}	15.6^{opq}	16.1^{opq}	20.3^{nop}	21.5^{mnop}	2.60	0.001	0.692	0.030
Soy[b]	3.2^{e}	1.9^{e}	31.3^{d}	32.1^{d}	26.1^{d}	35.5^{d}	2.2^{e}	4.9^{e}	22.2^{d}	25.0^{d}	21.4^{d}	28.5^{d}	3.01	0.001	0.322	0.922
Sweet[b]	0.4^{f}	3.2^{f}	6.5^{d}	9.4^{d}	6.1^{e}	6.6^{e}	0.7^{f}	1.4^{f}	10.4^{d}	10.1^{d}	5.2^{e}	6.8^{e}	1.36	0.001	0.931	0.500
Grass[b]	8.9	9.8	0.9	2.8	4.7	6.2	4.3	2.2	1.0	1.8	2.9	2.2	1.21	0.001	0.528	0.855
Other[b]	14.3	10.2	9.9	1.4	13.1	7.3	11.9	5.6	12.5	2.8	13.9	2.8	2.52	0.097	0.509	0.819
Tender[c]	50.1^{e}	36.0^{e}	65.4^{d}	59.6^{d}	70.6^{d}	60.9^{d}	50.1^{e}	43.3^{e}	62.9^{d}	56.4^{d}	62.6^{d}	61.6^{d}	2.83	0.001	0.392	0.456
Texture[c]	31.3^{j}	37.4^{i}	46.9^{gh}	41.3^{hi}	54.7^{g}	44.2^{gh}	35.6^{j}	42.4^{i}	50.5^{gh}	45.9^{hi}	48.2^{g}	48.9^{gh}	2.91	0.001	0.010	0.357
Juicy[c]	55.9^{h}	27.6^{i}	69.3^{g}	56.3^{h}	67.3^{g}	56.6^{h}	46.2^{h}	28.7^{i}	61.2^{g}	49.8^{h}	55.7^{g}	51.2^{h}	2.82	0.001	0.001	0.509

[a] Grass-animals finished on forage-based diet, Grain-animals finished on traditional grain-based diet

[b] Flavor scores based on 100 point scale, 0=very bland and 100=very strong

[c] Sensory scores based on 100 point scale, 0=very tough, very cohesive and very dry and 100=very tender, very mealy and very juicy

[d,e,f,] Means in a row with different superscripts differ ($P<0.05$) for Processing Treatment

[g,h,i,j] Means in a row with different superscripts differ ($P<0.05$) for Processing Treatment*Serving Temperature

[k,l,m,n,o,p,q] Means in a row with different superscripts differ ($P<0.05$) for Processing Treatment*Serving Temperature*Feed

Figure 1. Grassy off-flavor scores as affected by feed, processing treatment and aging period

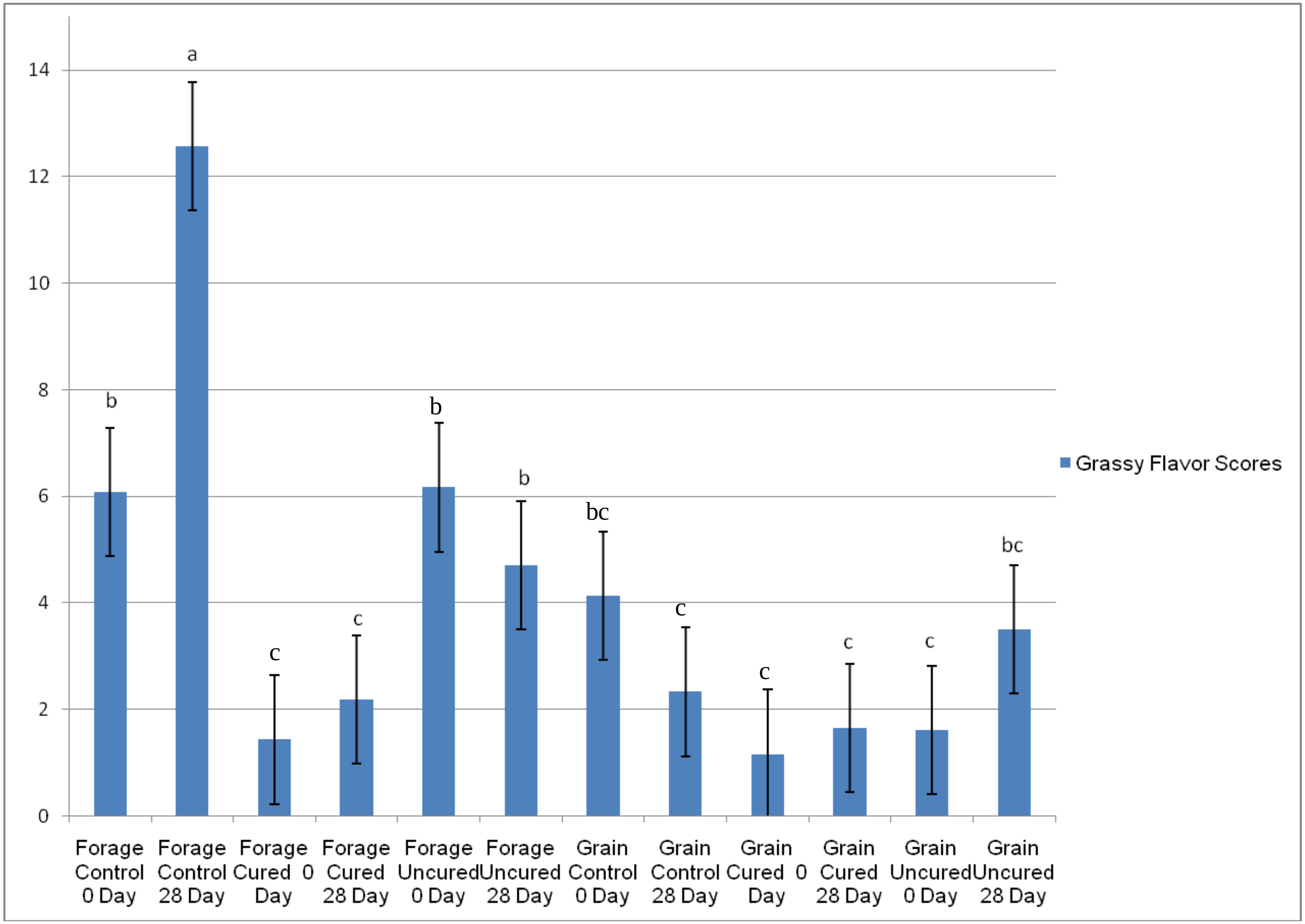
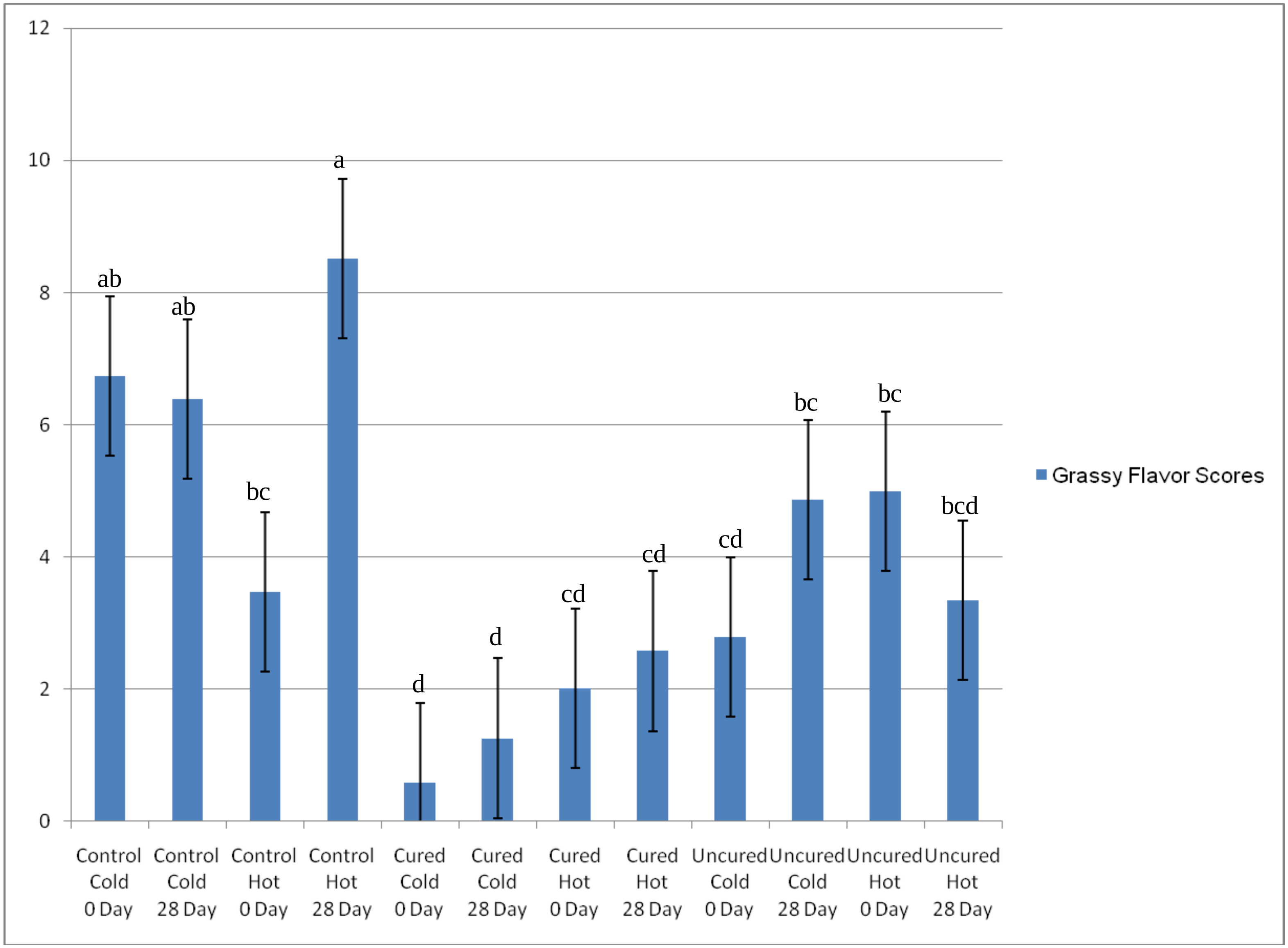


Figure 2. Grassy off-flavor scores as affected by processing treatment, serving temperature and aging period



Literature Cited

Abdullah, M., T.D Bidner, J.C. Carpenter, Jr., A.R. Schupp, J.E. Pontif and K.L. Koonce. 1979. Forage-Fed versus Short-Fed Beef as Influenced by Breed Type. Livestock Producers' Day Report. Louisiana State University. 19:146-151.

Aberle, E.D., J.C. Forrest, D.E. Gerrard and E.W. Mills. 2001. Principles of Meat Science, 4th Ed. Dubuqye, IA. Kendall/Hunt Publishing Company, pp 118-119.

Allen, V.G., J.P. Fontenot, R.F. Kelly, and D.R. Notter. 1996. Forage systems for beef production from conception to slaughter: III. Finishing systems. J. Anim. Sci. 74:625-638.

Bacus, J. 2006. Natural ingredients for cured and smoked meats. Proc. 59th AMSA Reciprocal Meats Conf. pp 77-78. American Meat Science Association, Savoy, IL.

Bagley, C.P. 1975. Effects of ration and climatic variables on steer performance. M.S. Thesis. Louisiana State University, Baton Rouge.

Bagley, C. P., G.M. Hill, J.W. Knox, D.F. Coombs, W.M. Oliver, A.F. Loyacano, W.E. Wyatt, D.C. Huffman, K.W. McMillin, and T.D. Bidner. 1988. Using forages to produce stocker and finished beef year-round. La Agric. Exp. Sta. Bull. pp 17-19.

Baublits, R.T., A.H. Brown, Jr., F.W. Pohlman, Z.B. Johnson, D.O. Onks, H.D. Loveday, R.E. Morrow, B.A. Sandelin, W.K. Coblentz, C.J. Richards, and R.B. Pugh. 2004. Carcass and beef color characteristics of three biological types of cattle grazing cool-season forages supplemented with soyhulls. Meat Sci. 68:297-303.

Bennet, L.L., A.C. Hammond, M.J. Williams, W.E. Kumkle, D.D. Johnson, R.L. Preston, and M.R. Miller. 1995. Performance, carcass yield, and carcass quality characteristics of steers finished on rhizoma peanut (Arachis glabrata)-tropical grass pasture or concentrate. J. Anim. Sci. 73:1881-1887.

Berthiaume, R., I. Mandell, L. Faucitano, and C. Lafreniere. 2006. Comparison of alternative beef production systems based on forage finishing or grain-forage diets with or without growth promotants: 1. Feedlot performance, carcass quality, and production costs. J. Anim. Sci. 84:2168-2177.

Bidner, T.D., N.R. Schupp, A.B. Mohamad, N.C. Rumore, R.E. Montgomery, C.P. Bagley and K.W. McMillin. 1986. Acceptability of beef from Angus-Hereford or Angus-Hereford-Brahman steers finished on all forage or a high energy diet. J. Anim. Sci. 62:381-387.

Boleman, S.J., S.L. Boleman, R.K. Miller, J.F. Taylor, H.R. Cross, T.L. Wheeler, M. Koohmaraie, S.D. Shackelford, M.F. Miller, R.L. West, D.D. Johnson, and J.W. Savell. 1997. Consumer evaluation of beef of known categories of tenderness. J. Anim. Sci. 75:1521-1524

Bowling, R.A., J.K. Riggs, G.C. Smith, Z.L. Carpenter, R.L. Reddish, and O.D. Butler. 1978. Production, carcass and palatability characteristics of steers produced by different management systems. J. Anim. Sci. 46:333-340.

Bretschneider, G., J.C. Elizalde, and F.A. Perez. 2008. The effect of feeding antibiotic growth promoters on the performance of beef cattle consuming forage-based diets: A review. Livestock Sci. 114:135-149.

Brewer, P. and C.R. Calkins. 2003. Quality traits of grain- and grass-fed beef: A review. Nebraska Beef Report. 2003:74-77.

Brown, H.G., S.L. Melton, M.J. Riemann, and W.R. Backus. 1979. Effects of energy intake and feed source on chemical changes and flavor of ground beef during frozen storage. J. Anim. Sci. 48:338-347.

Bruce, H.L., J.L. Stark, and S.L. Beilken. 2004. The effects of finishing diet and postmortem aging on the eating quality of the M. longissimus thoracis of electrically stimulate Brahman steer carcasses. Meat Sci. 67:261-268.

Calkins, C.R. and J.M. Hodgen. 2007. A fresh look at meat flavor. Meat Sci. 77:63-80.

Campo, M.M., G.R. Nute, S.I. Hughes, M. Enser, J.D. Wood, and R.I. Richardson. 2005. Flavour perception of oxidation in beef. Meat Sci. 72:303-311.

Clanton, D. C. 1977. Finishing cattle on pasture and other forages: irrigated pasture. J. Anim. Sci. 44:908-912.

Coughlin, J.R. 2006. Update on International Agency for Research on Cancer monograph on ingested nitrite and nitrate. Proceedings Meat Ind. Res. Conf., October, 2006. American Meat Science Association, Savoy, IL.

Cox, R.B., C.R. Kerth, J.G. Gentry, J.W. Prevatt, K.W. Braden, and W.R. Jones. 2006. Determining acceptance of domestic forage- or grain-finished beef by consumers from three southeastern U.S. states. J. Food Sci. 71:542-546.

Davies, H. Lloyd. 1977. Continued studies on the effect of grain or pasture on the carcass composition and meat quality of Friesian steers. Aust. J. Agric. 28:755-761.

Domingo, J.L., A. Bocio, G. Falco, J.M. Llobet. 2007. Benefits and risks of fish consumption: Part I. A quantitative analysis of the intake of omega-3 fatty acids and chemical contaminants. Toxicology 230:219-226.

Dunsing, M. 1959. Visual and eating preferences of consumer household panel for beef from animals of different age. Food Tech. 13:332.

Faucitano, L., P.Y. Chouinard, J. Fortin, I.B. Mandell, C. Lafreniere, C.L. Girard, and R.R. Berthiaume 2008. Comparison of alternative beef production systems based on forage finishing or grain-forage diets with or without growth promotants: 2. Meat quality, fatty acid composition and overall palatability. J. Anim. Sci. 86:1678-1689.

Forbes, S.M., C.M. Vaisey, and R. Diamant. 1974. The relationships between consumer criteria for choosing beef and beef quality. Can. Inst. Food Sci. Technol. J. 7:130-135.

French, P., E. G. O'Riordan, F. J. Monahan, P. J. Caffrey, M. T. Mooney, D. J. Troy, and A. P. Moloney. 2001. The eating quality of meat of steers fed grass and/or concentrates. Meat Sci. 57:379–386.

French, P., E.G. O'Riordan, E.J. Monahan, P.J. Caffrey, M. Vidal, M.T. Mooney, D.J. Troy, and A.P. Moloney. 2000. Meat quality of steers finished on autumn grass, grass silage or concentrate-based diets. Meat Sci. 56:173-180.

Goodson, K.J., W.W. Morgan, J.O. Reagan, B.L. Gwartney, S.M. Courington, and J.W. Wise. 2002. Beef customer satisfaction: Factors affecting consumer evaluations of clod steaks. J. Anim. Sci. 80:401-408.

Gray, J.L., and A.M. Pearson. 1994. Lipid derived off-flavours in meat-formation and inhibition. In: F. Shahidi, Editor, Flavour of Meat and Meat Products. Blackie Academic, London, pp. 116-143.

Grunert, K.G. 1997. What's in a steak? A cross-cultural study on the quality perception of beef. Food Quality and Preference 83:157–174.

Hodgson, Harlow J. 1977. Gaps in knowledge and technology for finishing cattle on forages. J. Anim. Sci. 44:896-900.

Huffman, D.C., and R. Boucher. 1987. Economic implications of production forage-fed beef. In: C.P. Bagley (Ed.). Year-round production of slaughter beef using optimum levels of forages. Louisiana Agricultural Experiment Station Bulletin. 781.

Jeremiah, L.E. 1996. The influence of subcutaneous fat thickness and marbling on beef: Palatability and consumer acceptability. Food Res. Int. 29:513-520.

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

Kerth, C.R., K.W. Braden, R. Cox, L.K. Kerth, and D.L. Rankins, Jr. 2006. Carcass, sensory, fat color, and consumer acceptance characteristics of Angus-cross steers finished on ryegrass (Lolium multiflorum) forage or on a high-concentrate diet. Meat Sci. 75:324-331.

Killinger, K.M., C.R., Calkins, W.J. Umberger, D.M. Feuz, and K.M. Eskridge. 2004. Consumer visual preference and value for beef steaks differing in marbling level and color. J. Anim. Sci. 82:3288-3293.

Krutulyte, Rasa, K.G. Grunert, Joachim Scholderer, Kit Skov Hagemann, Peter Elgaard, Brian Nielsen, Jens Peter Graverholt. 2008. Motivational factors for consuming omega-3 PUFAs: An exploratory study with Danish consumers. Appetite. 51:137-147.

Ladikos, D. and Lougovois, V. 1990. Lipid oxidation in muscle foods: A review. J. Food Chem. 35:295-314.

Mancini, R.A., and M.C. Hunt. 2005. Current Research in Meat Color. Meat Sci. 71:100-121.

Mandell, I.B., J.G. Buchanan-Smith, and C.P. Campbell. 1998. Effects of forage vs. grain feeding on carcass characteristics, fatty acid composition, and beef quality in Limousin-cross steers when time on feed is controlled. J. Anim. Sci. 76:2619-2630.

Marshall, D. M. 1994. Breed differences and genetic parameters for body composition traits in beef cattle. J. Anim. Sci. 72:2745–2755.

May, S.G., H.G. Dolezal, D.R. Gill, F.K. Ray, and D.S. Buchanan. Effect of days fed, carcass grade traits, and subcutaneous fat removal on postmortem muscle characteristics and beef palatability. J. Anim. Sci. 70:444-453.

McMillin, K.W., T.D. Bidner, G.M. Hill, C.P Bagley, J.W. Knox, D.F. Coombs, A.F. Loyacano, and W.M. Oliver. 1982. Carcass traits of slaughter beef finished on forage diets. Livestock Producers’ Day Report. 25:26-30.

McMillin, K.W., T.D. Bidner, R.E. Montgomery, M.J. Canal, J.T. Carothers, Y.C. Wu, and S.E. Felch. 1984. Mean carcass traits of slaughter cattle from the year round forage beef production project. Livestock Producers' Day Report. 25:26-30.

Medeiros, L.C., R.A. Field, D.J. Memkhaus, and W.C. Russell. 1987. Evaluation of range-grazed and concentrate fed beef by trained sensory panel, a household panel and a laboratory test market group. J. Sensory Stud. 2:259.

Melton, S.L., M. Amiri, G.W. Davis, and W.R. Backus. 1982. Flavor and chemical characteristics of ground beef from grass, forage-grain and grain-finished steers. J. Anim. Sci. 55:77-87.

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

Miller, M.F. , L.C. Hoover, A.L. Cook, A.L. Guerra, K.L. Huffman and K.S. Tinney. 1995. Consumer acceptability of beef steak tenderness in home and restaurant, J. Food Sci. 60:963–965.

Miller, R.K., J.D. Tatum, H.R. Cross, and J.D. Crouse. 1987. The influence of diet and time on feed on carcass traits and quality. Meat Sci. 19:303-313.

Mitchell, G. E., A. W. Reed, and S. E. Rogers. 1991. Influence of feeding regimen on the sensory qualities and fatty acid contents of beef steaks. J. Food Sci. 56:1102–1106.

National Academy of Sciences. 1981. The Health Effects of Nitrate, Nitrate and N-Nitroso Compounds. National Academy Press, Washington, D.C.

Oltjen, R. R., T. S. Rumsey, and P. A. Putnam. 1971. All-forage diets for finishing beef cattle. J. Anim. Sci. 32: 327.

Park, R.I. and P.L. Thomas. 1973. Factors affecting sheep meat flavor. Wool Technol. Sheep Breed. 1:69.

Poulson, C.S., T.R. Dhiman, A.L. Ure, D. Cornforth, and K.C. Olson. 2004. Conjugated linoleic acid content of beef from cattle fed diets containing high grain, CLA, or raised on forages. Livestock Production Sci. 91:117-128.

Reagan, J.O., K.V. STribling, J.A. Carpenter, and D.R. Champion. 1981. Microbiological, vacuum packaging and palatability attributes of beef produced at varied levels of forages and grains. J. Anim. Sci. 53:1482-1488.

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

Reverte, D., Y.L. Xiong, and W.G. Moody. 2003. Properties of restructured beef steaks from forage- and grain-fed cattle as affected by antioxidant and flavoring agents. Meat Sci. 65:539-546.

Robbins, K., J. Jensen, K.J. Ryan, C. Homco-Ryan, F.K. McKeith, and M.S. Brewer. 2003. Consumer attitudes towards beef and acceptability of enhanced beef. Meat Sci. 65:721-729.

Roberts, S.D., C.R. Kerth, K.W. Braden, D.L. Rankins, Jr., L. Kriese-Anderson, and J.W. Prevatt. 2009. Finishing steers on winter annual ryegrass (Lolium multiflorum Lam.) with varied levels of corn supplementation I:Effects on animal performance, carcass traits, and forage quality. J. Anim. Sci. 87:2690-2699.

Romans, J.R., W.J. Costello, C.W. Carlson, M.L. Greaser, K.W. Jones. 2001. The Meat We Eat. 14th Ed. Danville, IL. Interstate Publishers INC., pp 909-927.

Sapp, P.H., S.E. Williams, and M.A. McCann. 1999. Sensory attributes and retail display characteristics of pasture- and/or grain-fed beef aged 7, 14, or 21 days. Journal of Food Quality. 22:257-274.

Savell, J.W., H.R. Cross, J.J. Francis, J.W. Wise, D.S. Hale, D.L. Wilkes, and G.C. Smith. 1989. National consumer retail beef study: Interaction of trim level, price and grade on consumer acceptance of beef steaks and roasts. J. Food Qual. 12:251-274

Savell, J.W., R.E. Branson, H.R. Cross, D.M. Stiffler, J.W. Wise, D.B. Griffin, and G.C. Smith. 1987. National Consumer Retail Beef Study:Palatability evaluations of beef loins steaks that differed in marbling. J. Food Sci. 52:517-519, 532.

Schroeder, J.W., D.A. Cramer, R.A. Bowling, and C.W. Cook. 1980. Palatability, shelflife, and chemical differences between forage- and grain-finished beef. J. Anim. Sci. 50: 852-859.

Scollan, N., J.F. Hocquette, K. Nuernberg, D. Dannenberger, I. Richardson, and A. Moloney. 2006. Innovations in beef production systems that enhance the nutritional and health value of beef lipids and their relationship with meat quality. Meat Science. 74:13-33.

Sebranek, J.G. 1979. Advances in the technology of nitrite use and consideration of alternatives. Food Tech. 33(7): 58-62, 93.

Sebranek, J.G. and J. Bacus. 2007. Natural and Organic Cured Meat Products: Regulatory, Manufacturing, Marketing, Quality and Safety Issues. American Meat Science Association White Paper Series, Number 1.

Sindelar, J.J., J.C. Cordray, J.G. Sebranek, J.A. Love, D.U. Ahn. 2007a. Effects of varying levels of vegetable juice powder and incubation time on color, residual nitrate and nitrite, pigment, pH and sensory attributes of ready-to-eat uncured, emulsified frankfurter-style cooked sausage. J. Food Sci. 72 (5): 324-332.

Sindelar, J.J., J.C. Cordray, J.G. Sebranek, J.A. Love, D.U. Ahn. 2007b. Effects of varying levels of vegetable juice powder and incubation time on color, residual nitrate and nitrite, pigment, pH and sensory attributes of ready-to-eat uncured ham. J. Food Sci. 72 (6): 388-395.

Sitz, B.M., Calkins, C.R., D.M. Feuz, W.J. Umberger, and K.M. Eskridge. 2005. Consumer sensory acceptance and value of domestic, Canadian, and Australian grass-fed beef steaks. J. Anim. Sci. 83: 2863-2868.

Skibsted, L.H., A. Mikkelsen, and G. Bertelsen. 1998. Lipid-derived off-flavours in meat. In : F. Shahidi, Editor, Flavor of Meat, Meat Products and Seafoods, Blackie Academic, London, pp 217-247.

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

Smith, G.C., Z.L. Carpenter, H.R. Cross, C.E. Murphy, H.C. Abraham, J.W. Savell, G.W. Davis, B.W. Berry, and F.C. Parrish Jr. 1985. Relationship of USDA marbling groups to palatability of cooked beef. J. Food Qual. 7:289-308.

Smith, G.C., T.G. Jambers, Z.L. Carpenter, T.R. Dutson, R.L. Hostetler, and W.M. Oliver. 1979. Increasing the tenderness of forage-fed beef. J. Anim. Sci. 49:1207-1218.

Tatum, J.D., B.J. Klein, F.L. Williams, Jr., and R.A. Bowling. 1988. Influence of diet on growth rate and carcass composition of steers differing in frame size and muscle thickness. J. Anim. Sci. 66:1942-1954.

Spurway, R.A. 1972. Flavor differences in sheep meat. Food Technol. Aust. 24:645.

Theunissen, T.J.J.M., T. Kouwenhoven, and Y.H. Blauw. 1979. Consumer's responses to food products with increased levels of polyunsaturated fatty acids. J. Food Sci. 44:1483.

Umberger, W.J., D.M. Feuz, C.R. Calkins, and K. Killinger-Mann. 2002. U.S. consumer preference and willingness-to-pay for domestic corn-fed beef versus international grass-fed beef measured through an experimental auction. Agribusiness. 18:491-504.

Vestergaard, M., N. Oksberg, and P. Henckel. 2000. Influence of feeding intensity, grazing and finishing feeding on muscle fiber characteristics and meat color of semitendinosus, longissimus dorsi and supraspinatus muscles of young bulls. Meat Sci. 54:177-185.

Warren, H.E., N.D., Scollan, M. Enser, S.I. Hughes, R.I. Richardson, and J.D. Wood. 2007. Effects of breed and a concentrate or grass silage diet on beef quality in cattle with or without vitamin E supplement. Meat Sci. 78:270-278.

Wilson, J.R. 1984. Tropical pastures. In: D.J. Pearson (Ed.). Control of Crop Productivity. 185-197.

Wood, J.D., R.I. Richardson, G.R. Nut, A.V. Fisher, M.M. Campo, E. Kasapidou, P.R. Sheard, and M. Enser. 2003. Effects of fatty acids on meat quality: A review. Meat Sci. 66:21-32.

Yang, A., M.C. Lanari, M. Brewster, and R.K. Tume. 2001. Lipid stability and meat colour of beef from pasture- and grain-fed cattle with or without vitamin E supplement. Meat Sci. 60:41-50.

Appendix A.

Cook Cycle for Roasts

Step #	Type	Time	Smoke	Internal Temperature	Dry Bulb	Wet Bulb	RH%	DPT	Damper	Fan
1	Cook	999	OFF	150	180	180	100	177	Auto	High
2	Cook	020	OFF	199	150	150	100	149	Auto	High
3	Shower	005	OFF	150	000	000	000	100	Off	High

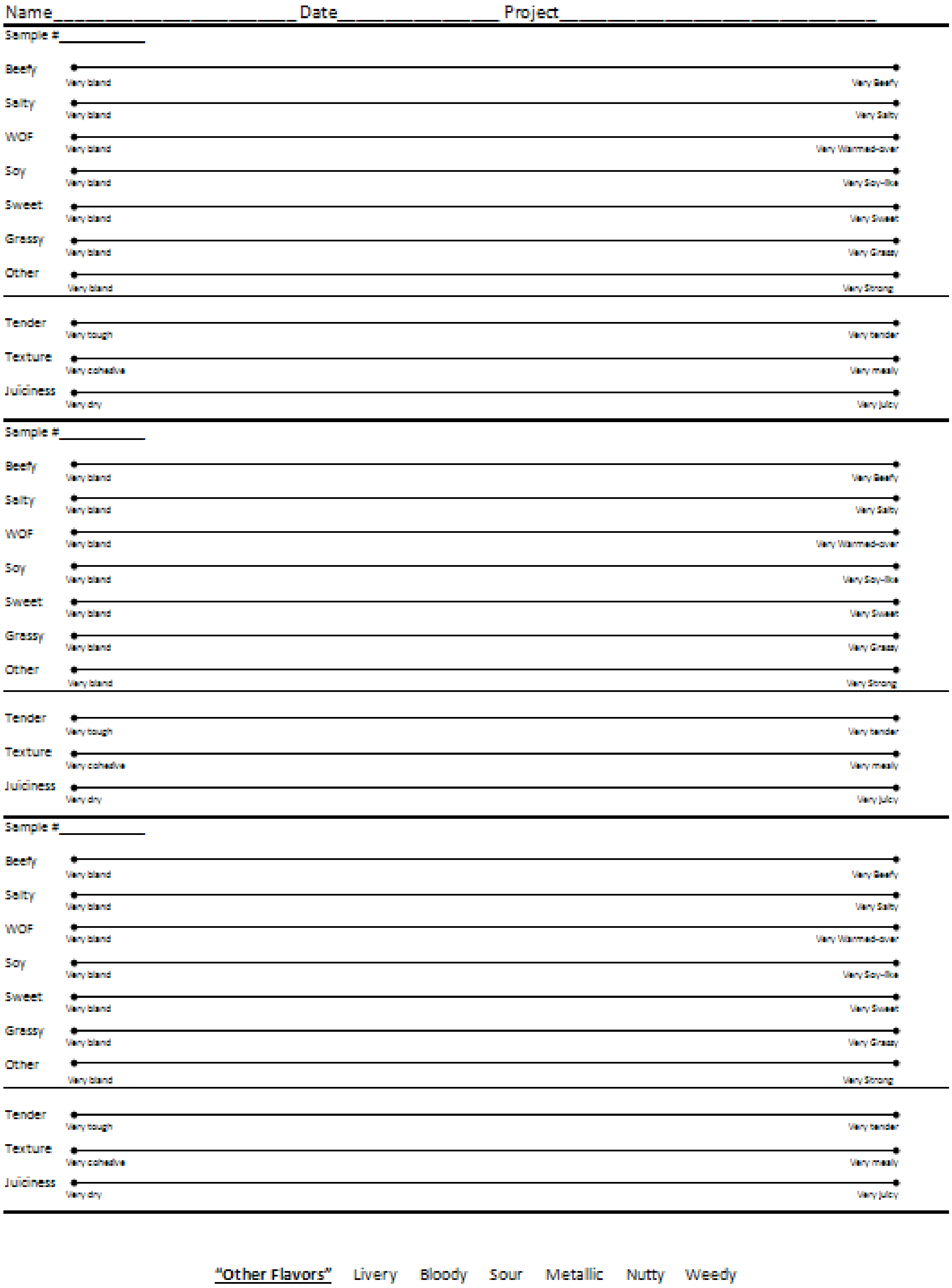
Appendix B.

Sensory Panel Definitions

Term	**Definition**	**Reference**
Beefy	Aromatics associated with cooked beef muscle meat. Combination of beefy and brothy/broth like.	conc. Beef broth
Bitter	Taste on tongue stimulated by solutions of caffeine, quinine and certain other alkaloids.	0.1% caffeine or quinine
Bloody	Aromatic taste sensation associated with raw lean meat, cooked blood, serum.	drip from raw beef
Cardboard	Aromatic associated with slightly oxidized fats and oils; reminiscent of wet cardboard packaging.	wet cardboard
Fishy	Aromatic associated with trimethlyamine and old fish.	fish oil
Gamey	Aromatic associated with muscle meat from wild game or from older lamb.	venison
Grassy	Green, slightly sweet aromatic associated with cut grass. In meat, flavor associated with beef fed a diet of primarily grasses.	50 ppm Cis-3-Hexen-1-ol
Livery	Aroma and flavor associated with cooked liver, organ meat, serum and/or blood salts.	brausweiger/liver patty in GB
Metallic	Aromatic associated with metals, tinny or iron.	penny in mouth
Soured	Aromatic associated with lactic or spoilage bacteria as in soured milk, soured meat, or soured dough. May be a controlled culture aromatic or indicative of spoilage.	buttermilk
Warmed Over	Aromatic characteristic of uncured cooked meat after 4 to 48 hours of refrigeration and reheating. Perceived as stale, cardboardy, or rancid.	bake GB overnight
Weedy	A combination of sharp, somewhat pungent, green weed-like aromatic.	10,000 ppm 2-Isobutylthiazole in propylene glycol

Appendix C.

Sensory Evaluation Sheet



Name__________________________ Date_________________ Project_________________________________

Sample #__________

Beefy	Very bland	Very Beefy
Salty	Very bland	Very Salty
WOF	Very bland	Very Warmed-over
Soy	Very bland	Very Soy-like
Sweet	Very bland	Very Sweet
Grassy	Very bland	Very Grassy
Other	Very bland	Very Strong
Tender	Very tough	Very tender
Texture	Very cohesive	Very mealy
Juiciness	Very dry	Very juicy

Sample #__________

Beefy	Very bland	Very Beefy
Salty	Very bland	Very Salty
WOF	Very bland	Very Warmed-over
Soy	Very bland	Very Soy-like
Sweet	Very bland	Very Sweet
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Other	Very bland	Very Strong
Tender	Very tough	Very tender
Texture	Very cohesive	Very mealy
Juiciness	Very dry	Very juicy

"Other Flavors" Livery Bloody Sour Metallic Nutty Weedy

Appendix D.

Thiobarbituric Acid Reactive Substances (TBARS) Assay

Extraction solution (TCA)
7.5% TCA (7.5 g/100 ml ddH2O or 75 g/L)
0.1% EDTA (0.1 g/100mL ddH2O or 1 g/L)
0.1% Propyl Gallate (0.1 g/100ml ddH2O or 1 g/L)

Standard (TEP)
1 mM/L Tetraethoxypropane (TEP)

TBA
1.15 g TBA in 100 ml (80 mM)

Standards:
235 µL of TEP into 1000 ml water = 1µM/ml
2 ml of TEP into 23 ml water = 80 nm/ml

	TEP (µL)	TCA (µL)	Pipette Setting
0	0	2000	1000 x 2
2	50	1950	975 x 2
4	100	1900	950 x 2
6	150	1850	925 x 2
8	200	1800	900 x 2
10	250	1750	875 x 2
20	500	1500	750 x 2
30	750	1250	625 x 2

Make standards in 16 ml tubes, VORTEX
Pipette 125 µL in first 3 columns of well.

Procedure:
- Mince and weigh 5 g of sample (±0.005 g) into a 50 ml centrifuge tube and add 15 ml TCA
- Homogenize for 20-30 s
- Centrifuge for 10 min. @ 1500 x g
- Filter with Whatman #4 into 16 mL glass tubes
- Load into 96 well plates by adding 125 µL sample and 125 µL TBA to each well (Load each sample and standard in triplicate) VORTEX samples and standards before loading
- Incubate microplate in shaker for 130 min at a shaker speed of 100, 40°C
- Read on spec at 540 nm
- Average three samples and create regression line
- Average of the three samples is put into regression equation to determine mg/ml