COMPARISON OF TENDERNESS, PALATABILITY AND RETAIL CASELIFE OF ENHANCED COW SUBPRIMALS TO CONTROL COW AND USDA SELECT SUBPRIMALS

By

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TABLE OF CONTENTS

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LIST OF TABLES

LIST OF TABLES

CHAPTER I

INTRODUCTION

Value added beef opportunities do not mean the beef industry needs to invent new products. Value added opportunities go as far back as the late 1970s when the Certified Angus Beef brand was developed and consumers had a 'label' that they believed provided the taste, price, safety and convenience that they expected in a beef product. Today, value added stems beyond labels and includes practices such as enhancement, packaging methods and pre-cooked meats.

Cow-calf producers cull cows when they show a decrease in overall performance. The slaughter cow industry segregates cull cows into different groups based on body condition scores. Fat cows with a body condition score of seven, eight, or nine are considered to be "breakers". Breakers are usually sold as boneless, wholesale cuts. Intermediate and poor conditioned cows are classified as a "boners". Boners are utilized mostly for ground beef or 100% visual lean product. Since whole muscle cuts provide a higher dollar value than ground beef, means by which "value" of whole muscle cuts can be increased should be investigated, ultimately resulting in improvements of overall consumer acceptability (Apple et al., 1999).

In 2008, mature cattle accounted for 17.8% of the total number of cattle slaughtered in the United States (USDA, 2008), thus representing an important source of meat for the beef industry. However, product from mature cattle could be classified as undesirable to consumers due to the typical characteristics of mature cow meat. It has been documented that mature cow meat is perceived to be less tender (Bouton et al., 1978) and tends to be darker in lean color (Boccard et al., 1978). The easiest solution to the quality problems with mature cow meat would be to produce ground beef. However, to increase the economic value of mature cow meat, processors can use different techniques, such as natural aging, the use of natural and artificial enzymes, electrical stimulation and enhancement to improve the tenderness, juiciness, and flavor. Research has also been conducted to investigate antemortem practices to help improve the quality of the end product. The objectives of this study were to determine the impact of enhancement of cow subprimals on tenderness, palatability, and retail caselife as compared to control cow subprimals and USDA Select subprimals.

CHAPTER II

REVIEW OF LITERATURE

Tenderness

Of all the factors that make up palatability, tenderness is the driving factor that will determine whether the consumer will have a satisfying eating experience (Boleman et al., 1997). Consumers convey that tenderness is the attribute most desired when eating a steak (Huffman et al., 1996). However, tenderness, being the most important factor of palatability, also contains the most variation. Variation in tenderness occurs within each carcass, between muscles and even varies within the same muscle (McKeith et al., 1985). As chronological age increases, tenderness decreases (Jeremiah, 1978; Smith et al., 1984). This toughing effect can also be termed age induced toughening. Bouton et al. (1978) stated that beef from older animals is tougher and drier upon first bite. There are many antemortem and postmortem factors that contribute to tenderness. These factors include genetics, type and location of muscle, type of diet, days on feed, amount of intramuscular fat, overall amount of connective tissue, and contractile protein state.

Two main factors determining overall tenderness are the amount of collagen and contractile protein state. The total collagen content within beef muscles varies from 1% to 15% of dry weight (Purslow, 2005). Linkages within the collagen toughen and become less heat soluble with age. In younger animals, cross-linkages are newly formed, thus degrade easily with applied heat (Marsh, 1977). With age, it is generally accepted that the development of mature cross links cause an increase in cooked meat toughness (Bailey and Light, 1989). Age induced toughening could be from the thickness of perimysial sheets within muscles. Differences in animal age, specie, and muscle all contribute to the variation in the thickness of the perimysial sheets (Lepetit, 2007). In a study researching tenderness and oxidative stability of post-mortem muscles from mature cows of various ages, Xiong et al. (2007) revealed that *longissimus dorsi* (LD) steaks from ten to twelve year old cows were less tender than six to eight year old cows and two to four year old cows. Furthermore, LD steaks from the six to eight year old cows were less tender than the two to four year old cows Xiong et al. (2007). Warner-Bratzler shear force (WBSF) and sensory panelist values for loin steaks were higher from loin steaks from A maturity carcasses than C maturity carcasses were compared, indicating that steaks from A maturity carcasses were more tender (Field et al., 1997).

To determine tenderness of meat, researchers can use WBSF values. From these values, researchers can segregate different muscles into tender and tough categories. Warner-Bratzler shear force values are also used to help compare tenderness evaluations to results from a sensory panel. Having an objective measurement of tenderness is very important because every consumer's threshold for tenderness is different. Many tenderness studies examine the LD muscle because it is perceived to be one of the more tender cuts, possessing a higher value, on a carcass. Researchers also believed that the LD could give insight into tenderness of other muscles (Belew et al., 2003). Results from a tenderness study looking at tenderness of seventeen different beef cuts revealed that the

LD was ranked the in top ten for tenderness and the tenderness increased with postmortem aging (Gruber et. al, 2006).

In a study comparing WBSF values of 40 different bovine muscles, Belew et al. (2003) documented that the LD was more tender than the *M. gluteus medius*. Tenderness values were divided into categories: “very tender” below 3.2 kg, “tender” between 3.2 and 3.9 kg, “intermediate” between 3.9 and 4.6 kg, and “tough” identified as greater than 4.6 kg. Having identified those categories, the LD and *M. gluteus medius* were each classified as tender (Belew et al., 2003).

Improvements to tenderness have been researched for many years. One major antemortem practice producers utilize to improve the quality of cull cows is feeding a concentrate diet at least 60 d prior to slaughter to reduce age-associated toughening of beef. High concentrate diets increase the amount of heat soluble collagen (Boleman et al., 1996). Stelzleni et al. (2007) reported fed beef cull cows had brighter lean, possessed whiter external fat, and were more tender then non-fed cull cows. Boleman et al. (1996) reported that realimented cull cows were rated as being more tender than non-realimented cull cows. Boleman et al. (1996) also stated with the feeding of high energy diets, myofibrillar fragmentation became easier and detectable connective tissue decreased.

Palatability

Palatability includes tenderness, juiciness, and flavor. As mentioned above, tenderness has been proven to be the driving factor of consumer acceptance, but tenderness is interlinked with juiciness and flavor. This halo effect means that one trait will influence the consumer perception of the other two traits. Meat from mature cows tends to demonstrate problems with all the palatability factors. In results from a sensory panel that compared non fed beef cows to fed beef and dairy cull cows and non fed dairy cull cows, researchers reported that the intensity of off flavors increased significantly when panelists evaluated beef-non fed samples (Stelzleni et al., 2007). Sensory quality is affected by productive and technological factors, such as refrigeration and aging time (Monsón et al., 2005). Researchers have identified these problems by conducting consumer and trained sensory panels. Consumer sensory panels are conducted to identify consumer response to a product. General questions about the product, as well as, identifying demographics about the consumers are usually listed on a consumer ballot. Variation could be eliminated by training panelists on certain sensory attributes, thus creating a memory of the attributes and applying it to actual research tests (Cross et al., 1978). However, there are still many factors that are involved when a consumer brings home meat from the store. There are differences in preparation such as, cooking method, degree of doneness, and different seasonings, which will create variation among consumer responses (Lorenzen et al., 2003). Numerous factors play a role in consumers eating experience at home. The main factor that will determine tenderness in a steak for a consumer is degree of doneness and cooking method. Consumer preference for degree of doneness cannot be controlled and has a major effect on consumer satisfaction in the home and dining out (Lorenzen et al., 1999). In a previous study evaluating consumer acceptability of steaks in restaurants based on degree of doneness, Cox et al. (1997)

discovered if a consumer considered the steak over or under the desired degree of doneness the overall rating for that steak declined significantly.

Another consumer study conducted by Platter et al. (2005) revealed a consumer would be willing to pay a higher price for steaks that are deemed tender, than those steaks identified as slightly tender, slightly tough, or very tough. Robbins et al. (2003) conducted a consumer sensory panel to observe consumer attitudes towards beef and acceptability of enhanced beef. Based on a consumer beef attitude questionnaire, consumer's ideal steak was somewhat marbled and moderately bright red. Consumers also reported an ideal steak should be tender, juicy, and have an intense beef flavor (Robbins et al., 2003a). Improving consumer acceptance of steaks would increase the demand of beef. Being able to influence consumer purchasing decisions by introducing marbling scores and WBSF values would help position the beef products in the marketplace (Platter et al., 2005)

To improve sensory attributes of mature cow meat, researchers have studied injecting different enhancement solutions to determine the effects of the solution on overall palatability. Results from a study looking at the sensory and physical characteristics of enhanced cow meat versus non-enhanced cow meat products, report that enhanced cow loin steaks are more tender and juicy than control steaks and also have a pinker color during vacuum storage, after being allowed to bloom and after cooking (Hoffman, 2006). Furthermore, enhanced cow loin steaks did not have a higher rating for intense beef flavor when compared to control steaks (Hoffman, 2006). In another study looking at the impact of sodium chloride concentration and muscle type on the quality, sensory, and instrumental color characteristics of whole muscle beef, Baublits et al. (2006), revealed that the sensory panelists were unable to detect any off flavors, beef intensity, or salt intensity across all treatments. Furthermore, the sensory panelists concluded there were similar flavors between treatments and muscle groups.

Aging

Aging is a very common postmortem practice used to increase palatability traits such as tenderness, juiciness, and flavor. During wet aging the product is vacuumed packaged and put into dark storage for certain length of time. Vacuum packaging has enabled aging to be utilized on a large scale without an excessive loss of product through premature spoilage and evaporation (Husband and Johnson, 1985). Dry aging refers to carcasses or wholesale cuts that have no protective covering. Both aging processes give two very different and distinct flavors. During the aging process, enzymes attack the myofibrillar structure of the muscle and breakdown the proteins (Husband and Johnson, 1985). The calpain proteolytic system has been proved to be responsible for the postmortem proteolysis involved in meat tenderness. There are other factors, such as rate of pH decline and temperature decline during rigor mortis, that influence the tenderization process (Koohmaraie, 1994). As an animal matures, the rate of protein degradation during aging steadily decreases. It has been hypothesized that muscle from older cows has reduced calpain activity due to greater oxidative stress, which, in turn, increases toughness when compared to muscle from younger animals (Xiong et al., 2007). In a study looking at changes in mechanical strength of intramuscular connective tissue during postmortem aging of beef, results showed that at least 29% of postmortem aging occurs between 10 and 14 d (Nishimura et al., 1998). Mandell et al. (2006) looked at skeletal separation and aging effects on cull cow beef. Results showed an increase in tenderness of loin steaks from each of the four aging periods: 2, 7, 14, and 28 d (Mandell et al., 2006). These results agree with Gruber et al. (2006) who documented that both USDA Select and USDA Choice loins increased in tenderness from 14 d to 28 d of postmortem aging. In addition, when comparing the WBSF values from mature cows of various ages, tenderness progressively improved during post-mortem storage across all storage times (Xiong et al., 2007).

Case life

Improving case life of retail ready beef has been studied by using different packaging types. Storage life of retail ready beef cuts must be sufficient to allow widespread distribution and merchandising (Jeremiah and Gibson, 2001). Packaging also needs to eliminate microbial spoilage and prolong color of the meat. Discoloration will eventually develop if oxygen moves through the packaging film (Jeremiah and Gibson, 2001). The color of lean on the surface of a beef product, along with other factors, influences the consumer's purchasing decisions.

Consumers associate bright red color of lean of beef with being fresh, which ultimately will determine whether or not they decide to buy the product. The intensity of the color of red of exposed lean tissue is determined by antemortem factors such as species, stress, sex, and age of animal; and postmortem factors including rate of pH decline and ultimate pH of the meat product (Seideman et al., 1983). Color and the intensity of that color of the lean provide a challenge for mature cow meat in a retail display. As an animal matures, the color of lean gets darker due to a higher concentration of myoglobin present in the muscle (Boccard et al., 1979). A couple of main factors that affect meat color are environmental effects, diet of animal, and physiological age. To improve the overall quality of mature cattle, research has been done to improve the fat color and lean color. One way researchers are trying to improve the color of lean and the color of external fat is by grain supplementing the cull cows for at least 56 d. Fed cows in this study were given a 56% concentrate (DM) warm up diet for 7 d, then adjusted to a 80% concentrate (DM) diet, which contained 11.9% crude protein. Selected cows were also implanted or not implanted. The results show that implanting had no effect on the carcass characteristics of the cows. Hunterlab L*, a*, and b* values for cows on 56 d grain supplementation, were higher than cows fed 0 and 28 d, thus indicating a brighter cherry red lean (Cranwell et al., 1996). It was also determined in this same study that cows fed a warm up diet of 56% concentrate then adjusted to a 80% concentrate diet with 11.9% crude protein for 56 d had a whiter color of external fat (Cranwell et al., 1996). In another study, cattle that had been grain supplemented for 193 d prior to slaughter had improved lean color and a decrease in surface discoloration, as compared to grass fed cattle (Reagan et al., 1977). Results from this study concluded that after 3 d of display grass fed cattle were significantly lower in overall color scores than grain fed cattle (Reagan et al., 1977).

During storage of retail ready beef lipid oxidation occurs, thus limiting the storage or shelf life of meat exposed to oxygen under conditions where microbial spoilage is prevented or reduced, such as refrigeration or freezing (Campo et al., 2005). Very little research has been done on the effects of physiological age and rate of oxidation on meat products. From the research that has been conducted, it can be speculated that age related loss in the redox potential may occur in mature cows and predispose post-mortem muscles to a higher rate of oxidation (Xiong et al., 2007). There are also differences in the rate of surface discoloration between the muscles. Higher pigmented muscles will remain bright red for longer due to the amount of enzymatic reducing activity (MRA) in the muscle. The MRA is accelerated by increasing the temperature and pH. Therefore, when the MRA decreases brown metmyoglobin will begin to appear on the surface of the meat.

Lipid oxidation produces certain off flavors during storage due to free radicals. The free radicals generated during the redox activity of myoglobin have been suggested to attack lipids in membranes initiating lipid oxidation chain reactions (Monahan et al., 2005). To help stop lipid oxidation, research has been conducted to evaluate the effects of antioxidants. Antioxidants react with the free radicals to slow down the lipid oxidation process. Feeding vitamin E to cattle prior to slaughter has been shown to prolong the shelf life and maintain the color of product when compared to controls (Monahan et al., 2005). Another strategy is to add antioxidants to enhancement solutions to try and help prevent lipid oxidation in postmortem muscles. This strategy could also be helpful in enhancement solutions containing higher levels of salt. Enhancement solutions containing higher levels of sodium chloride have negative effects on color stability due to salt induced oxidation (Hoffman, 2006).

A study evaluating tenderness and oxidative stability of postmortem muscles from mature cows of various ages revealed that meat from ten to twelve year old cows were more susceptible to lipid oxidation than meat from six to eight year old cows which, in turn, was more susceptible than meat from two to four year old cows (Xiong et al., 2007). It was concluded that antioxidative strategies are needed to improve the oxidative stability and flavor of mature cow meat (Xiong et al., 2007).

It is evident that meat from mature cows falls short of consumer standards from a palatability standpoint, as well as a case life standpoint. However, researchers are getting closer to finding new technologies to better improve mature cow product. Antemortem practices, such as grain supplementation, have been shown to improve the overall quality of mature cow meat. However, with current feed prices remaining high, alternative methods need to be researched. Postmortem research has shown that by enhancing mature cow meat, tenderness, juiciness, and case life has improved. However, issues still exist with consistency of flavor and color attributes. In order to improve the overall quality of mature cow meat more research needs to be conducted to help improve the enhancement process and the effects on flavor and color. Past research has investigated the effects of enhancement solutions on various mature cow meat products and comparing them with control cow meat products. However, in this study research will be conducted to investigate the effects of enhancement solutions of mature cow meat products and compare those with USDA Select subprimals to see the relationship between them.

CHAPTER III

COMPARISON OF TENDERNESS, PALATABILITY, AND RETAIL CASELIFE OF ENHANCED SUBPRIMALS TO CONTROL COW AND USDA SELECT SUBPRIMALS

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ABSTRACT

Products from mature cattle are often perceived as undesirable by consumers due to typical characteristics associated with cow meat. Mature cow meat has been documented to be less tender and have darker lean color. The objective of this study was to determine the effects of enhancing cow subprimals on tenderness, palatability, and retail case life compared to non-enhanced cow and USDA Select subprimals. Strip loin, top sirloin butt, and ribeye subprimals were selected (n = 20 per treatment). Steaks were cut and aged for 14, 21, or 28 d. Warner-Bratzler shear force values of ribeye steaks from the non-enhanced cow over all age groups, were significantly tougher ($P < 0.05$) than other treatment × age interactions. Furthermore, top sirloin butts from non-enhanced cow were tougher ($P < 0.05$) at 14 and 28 d compared to other treatments. Warner-Bratzler shear force and cook loss values for strip loins were significant ($P < 0.05$) by treatment over all aging periods. Non-enhanced cow steaks had higher shear force (4.58 ± 0.15 kg) and cook loss (20.70 ± 0.68 kg) than enhanced cow (3.90 ± 0.14 kg; 14.32 ± 0.69 kg) and

USDA Select steaks (3.09 ± 0.14 kg; 15.01 ± 0.68 kg). Sensory data concluded that enhanced cow steaks from all subprimals were higher ($P < 0.05$) for initial juiciness for both aging periods, compared to non-enhanced cow and USDA Select. Overall, tenderness values evaluated for enhanced cow and USDA Select subprimals were significantly higher ($P < 0.05$) than non-enhanced subprimals. Non-enhanced subprimals contained the highest amount of connective tissue ($P < 0.05$). Enhanced cow steaks from all three subprimals were lower ($P < 0.05$) in beef flavor and higher in salty flavor. Non-enhanced ribeyes and strip loins displayed a higher soapy off flavor ($P < 0.05$). Non-enhanced ribeyes and top sirloin butts were higher ($P < 0.05$) in grassy/cowy off flavor. When analyzing subjective color scores during retail case life, USDA Select ribeye and strip loin steaks aged 14 d were deemed slightly dark cherry red ($P < 0.05$) when compared to 21 and 28 d aged steaks. Select top sirloin butts were considered moderately dark cherry red in color over all aging periods. Non-enhanced cow steaks from all three subprimals had the highest amount ($P < 0.05$) of surface discoloration. Enhanced cow strip loins had the lowest ($P < 0.05$) L* and b* values over all aging periods, while USDA Select strip loins at 28 d had the lowest ($P < 0.05$) a* value. The USDA Select top sirloin butt steaks had the highest ($P < 0.05$) b* value over all aging periods. It was concluded that enhanced cow steaks were comparable to USDA Select steaks relative to a tenderness and juiciness. However, more research needs to be conducted to further improve the effects of enhancement solutions on color stability.

Keywords: cow, enhanced, palatability, caselife, tenderness

INTRODUCTION

Value added efforts in the beef industry go as far back as the late 1970s when the Certified Angus Beef brand was developed and consumers had a ‘label’ that they believed provided the taste, price, safety and convenience that they expected in a beef product. Today, value added stems beyond labels and includes practices such as enhancement, packaging methods and pre-cooked meats. Enhancement of current products presents a significant opportunity to increase consumer demand and returns to beef producers.

Cow-calf producers cull cows when they show a decrease in overall performance. The slaughter cow industry segregates cull cows into different groups based on body condition scores. Fat cows with a body condition score (BCS) of seven, eight, or nine are considered to be “breakers”. Breakers are usually sold as boneless, wholesale cuts. Intermediate and poor conditioned cows are classified as a “boners”. Boners are utilized mostly for ground beef or 100% visual lean product. In the national market cow and bull beef quality audit-1999, researchers recorded that of the cows audited, 2.3% of cows received a BCS of 1 or 2 and 4.5% of beef cows received a BCS of 8 or 9 (Roeber et al., 2001). With 4.5% of cows receiving a body score of 8 or 9 (Roeber et al., 2001) that provides the industry with whole muscle cuts which in turn will provide a higher dollar value than ground beef, means by which “value” can be increased should be investigated, ultimately resulting in improvements of overall consumer acceptability (Apple et al., 1999).

In 2008, mature cattle accounted for 17.8% of the total number of cattle slaughtered in the United States (USDA, 2008), thus representing an important source of meat for the beef industry. However, product from mature cattle could be classified as undesirable to consumers due to the typical characteristics of mature cow meat. It has been documented that mature cow meat is perceived to be less tender (Bouton et al., 1978) and tends to be darker in lean color (Boccard et al., 1979).The easiest solution to the quality problems with mature cow meat would be to produce ground beef. However, to increase the economic value of mature cow meat, processors can use different techniques, such as, natural aging, the use of natural and artificial enzymes, electrical stimulation and enhancement to produce a higher quality product by increasing the tenderness, juiciness, and flavor. Research has also been conducted to investigate antemortem practices to help improve the quality of the end product. Past research has investigated the effects of enhancement solution on overall quality of mature cow meat products, comparing them to control mature cow meat products, however there is no research comparing overall quality of mature cow meat products to USDA Select subprimals. The objectives of this study were to determine the impact of enhancement of cow subprimals on tenderness, palatability, and retail caselife as compared to control cow subprimals and USDA Select subprimals.

MATERIALS AND METHODS

Subprimals

Two sources of subprimals were used in this study. Subprimals (strip loins, top sirloin butts, and ribeyes) were selected (n = 20 subprimals per treatment). The subprimals were aged for 14, 21, or 28 d time periods. The cow product (n = 40 per subprimal) was received from a Texas processor, and randomly divided into two different treatment groups, normal cow product (n = 20 per subprimal) and enhanced cow product (n = 20 per subprimal). The USDA Select product (n = 20 per subprimals) was purchased from a commercial packing facility in Perkins, Oklahoma.

After subprimals aged for 14 d, half of the cow product (n = 20) was injected with an enhancement solution, up to 10% of the initial weight. The subprimals were allowed to equilibrate for 15 minutes before cutting steaks. The enhancement solution consisted of Brifisol 750, Cargill Hi-grade salt, Vivox Antioxidant, Purasal P Plus (78%), Proliant B1301 Beef stock, water and ice. A total of ten, 2.54 cm steaks were cut from each subprimal. The first three steaks were identified for Warner-Bratzler shear force (WBSF), the next four steaks were used for sensory evaluation, and the last three steaks were used for simulated retail display. Each steak selected for WBSF analysis and simulated retail display was assigned one of three aging periods: 14, 21, or 28 d. Steaks used for sensory evaluations were assigned into one of two aging periods: 14 or 28 d. The steaks selected for sensory and WBSF were vacuum packaged and frozen in a (-20º C to -40º C) blast freezer after the appropriate aging time and then stored in a freezer (-10º C) until further analysis.

Simulated Retail Display

The steaks were placed on a styrofoam tray with a soaker pad and were over-wrapped with a polyvinyl chloride film (PVC). Trays were placed into the coffin style display case which was maintained at 2°C ± 1, under continuous lighting (Philips Delux

Warm White Florescent lamps) for 24 h per d. The surface of the meat was exposed to light (900 to 1365 lux) as recommended by AMSA (1991). Each steak was objectively and subjectively evaluated for color attributes at 12 h intervals during the retail display until the steaks were deemed to be ~80% undesirable, having a mean overall appearance score of 3 (moderately undesirable) or lower.

Objective Color Evaluation

Color of each steak was measured using a HunterLab MiniScan XE hand-held spectrophotometer equipped with a 6 mm aperture (HunterLab Associates, Inc., Reston, VA) to determine values for CIE L* (brightness; 0 = black, 100 = white), a* (redness/greenness; positive values = red, negative values = green), and b* (yellowness/blueness; positive values = yellow, negative values = blue) which followed the procedures of the Commission International de l'Eclairage (CIE, 1976). Three readings were taken for each steak and the readings were averaged to obtain the L*, a*, and b* values for each steak at each time of evaluation.

Subjective Color Evaluation

Subjective color was evaluated by a six person, trained panel of Oklahoma State University personnel. Panelists were trained using Munsell color tiles and were required to receive a passing score before participating on a color panel. Panelists assigned scores to each steak for muscle color, surface discoloration, and overall appearance at each evaluation time. Muscle color (oxygenated pigment) was characterized on an 8-point scale (8 = extremely bright cherry-red; 1= extremely dark red) as outlined by in the Guidelines for Meat Color Evaluation (AMSA, 1991). The amount of surface discoloration was determined by a 7-point scale [7= total discoloration (100%); 1 = no discoloration (0%)]. Overall appearance was depicted by an 8-point scale (8 = extremely desirable, 1 = extremely undesirable).

Warner-Bratzler Shear Force

Steaks identified for WBSF were allowed to thaw for 24 hr at 4°C prior to cooking. Steaks were cooked on an impingement oven (model 1132-000-A; Lincoln Impinger, Fort Wayne, IN) at 180°C to an internal temperature of 70°C. Internal steak temperatures were monitored with thermocouples (model OM-202;Omega Engineering, Inc., Stamford,CT.). Individual steak weights were recorded prior to and following cooking to determine percentage cook loss.

Following cooking, steaks were allowed to cool for 24 h at 4° C before determining shear force values. Six cores were taken from each steak; cores were 1.27 cm in diameter and removed parallel to the muscle fiber orientation from each steak. The cores were sheared once by a Warner-Bratzler head attached to an Instron Universal Testing Machine (model 4502; Instron Corp., Canton, MA) at a crosshead speed of 200 mm/min. Peak force (kg) of cores was recorded by an IBM PS2 (Model 55 SX) using software provided by the Instron Corp. (Canton, MA). Mean peak WBSF was then calculated by averaging the six cores.

Sensory

Steaks were assigned a randomized three digit number before sensory sessions and were randomized into a session by subprimal. Each session was randomized to include each aging category and treatment combination. Steaks were allowed to thaw 24 h prior to each session. Steaks were cooked following same procedures as described for WBSF. Samples were uniformly cut from each steak and placed in a cup with the corresponding identification number. Cups were then placed in a warmer (Food Warming Equipment, Model PS-1220-15, Crystal Lake, IL) until served.

Sensory panel consisted of eight trained Oklahoma State personnel. Panelists were trained for tenderness, juiciness, and five specific flavor attributes (Cross et al., 1978). Sensory sessions were conducted twice a day, three days a week for two weeks, and contained 12 samples each. Samples were evaluated using a standard ballot from the American Meat Science Association (AMSA, 1995). This standard ballot consisted of a numerical, eight point scale for initial and sustained juiciness, tenderness and connective tissue amount (8 = extremely juicy, tender, none, 1= extremely dry, tough, abundant). Five flavor attributes were evaluated and included beef flavor, salty, soapy, painty/fishy, and grassy/cow. The flavor intensity was scored on a 3-point scale; [not detectable (1) to strongly detectable (3)].

During sessions, panelists were randomly seated in individual booths in a temperature and light controlled room. While samples were 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 in order to cleanse their palate.

Statistical Analysis

Data were analyzed, by subprimal, using the mixed procedure of SAS. The analysis of variance model for WBSF and cook loss included treatment and age as the fixed effects and identification number as the random effect. The analysis of variance model for sensory traits included treatment and age as the fixed main effects, and panelist and identification number 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, identification number as the subject, and treatment and age as the fixed effects. All models also included primary and secondary interaction effects. The least squares means were separated using a pairwise t-test when the model displayed a treatment effect ($\alpha < 0.05$).

RESULTS AND DISCUSSION

Warner-Bratzler Shear Force

Warner-Bratzler shear force values are presented in Table 1 for ribeyes and top sirloin butts by treatment and aging category. The treatment by aging interaction was significant for WBSF for ribeyes and top sirloin butts. Non-enhanced cow ribeyes, over all aging periods (14, 21, 28 d), were significantly tougher ($P < 0.05$) than the enhanced cow and USDA Select steaks. These results agreed with a previous study that determined that *longissimus dorsi* (LD) steaks from cows 10 -12 y in age were tougher than LD steaks from A maturity cattle (Xiong et al., 2007). Shear force for non-enhanced cow top sirloin butt steaks were significantly tougher ($P < 0.05$) for all aging periods, than enhanced cow and USDA Select steaks. Warner-Bratzler shear force values for enhanced cow were also lower than non-enhanced cow. Enhancement solutions have been found to improve the tenderness of meat products due to salt, phosphate, and water. Robbins et al., 2002, found that tenderness values for enhanced round steaks were higher from sensory evaluation and lower from WBSF (Robbins et al., 2002).

Warner-Bratzler shear force was significant for strip loins by treatment. Non-enhanced cow was significantly tougher than the enhanced cow and USDA Select steaks over all aging periods (averaged for 14, 21, and 28 d; Table 2). These results were supported by a study conducted by Hunsley et al. (1971), which indicated WBSF values from LD were higher for bulls across all age groups when compared to steers. There was a significant treatment and age interaction for the means of WBSF on top sirloin butts. Table 1 documents that the non-enhanced cow top sirloin butt steaks were significantly tougher at 14 and 28 d aging periods than the enhanced cow and USDA Select steaks. In a study, looking at aging and enhancement effects on quality characteristics of beef strip steaks, enhanced steaks were more tender than controls across 7, 14, 21, and 28 d aging periods. The enhanced strip steaks did not improve tenderness past 14 d age (Wicklund et al., 2005).

Cook Loss

Cook loss was significant by treatment. Non-enhanced cow steaks had the highest percentage cook loss and enhanced cow steaks had the lowest percentage cook loss (Table 1) for ribeyes, top sirloin butt, and strip loin steaks (Table 2). These results for cook loss are supported by a previous study that showed enhanced beef steaks possessed a numerically lower cook loss than the controls (Robbins et al., 2003a). In another study looking at marinated fresh and precooked pork, Cannon et al. (1993) found that phosphate enhanced pork possessed lower cook loss percentages. This supports that phosphates increase water holding capacity, decreasing cook loss percentages.

Sensory

Enhanced cow steaks were ranked higher for both initial and sustained juiciness ($P < 0.05$) over both aging periods (14 and 28 d) as compared to non-enhanced cow and Select ribeye, strip loin, and top sirloin butt steaks (Table 3). These data are supported by the research on enhanced beef, which found that enhanced beef was juicier than non-enhanced beef. These results were supported by a previous study that suggests enhanced steaks were significantly more tender and juicier than non-enhanced beef (Robbins et al., 2003a). In a previous study involving injection of calcium chloride into strip loins, researchers documented that the injected strip loins were juicier than the controls (Morgan et al., 1991). Non-enhanced cow and Select ribeye and top sirloin butt steaks were similar in initial juiciness and sustained juiciness (Table 3). However, non-enhanced cow strip loin steaks were juicier than Select steaks when rated for initial and sustained juiciness (Table 3) over both aging periods.

Aging period was also significant for initial and sustained juiciness for top sirloin butts steaks ($P < 0.05$). Data revealed 14 d steaks were juicier when rated for initial juiciness (4.78 ± 0.11 vs. 4.34 ± 0.16) and sustained juiciness (4.91 ± 0.14 vs. 4.46 ± 0.11) as compared to 28 d aged steaks (data not presented in tabular form).

Least squares means for tenderness and connective tissue amount by treatment for ribeyes over both aging periods are presented in Table 4. Enhanced cow ribeye steaks were more tender when rated for first impression tenderness ($P < 0.05$) than non-enhanced and USDA Select ribeye steaks; Select ribeye steaks were more tender than non-enhanced cow ribeye steaks. However, enhanced cow ribeye steaks performed similar to Select ribeye steaks on overall impression of tenderness and connective tissue amount ($P > 0.05$). Non-enhanced cow ribeye steaks were significantly less tender on first impression and overall tenderness ($P < 0.05$), as well as had more connective tissue, as compared to enhanced cow and Select ribeye steaks (Table 4). The amount of connective tissue is variable within muscles and also with animal age (Purslow, 2005). The results on connective tissue amount and the effects on tenderness associated with it in ribeyes were supported with a study that explained as an animal increases in age, collagen becomes tougher due to the age-dependant strengthening of bonds (Marsh, 1977). The strength of bonds in the connective tissue within the meat product influences the tenderness of a meat product (Purslow, 2005).

Results for tenderness and connective tissue amount for strip loin steaks and top sirloin butt steaks are also presented in Table 4. Non-enhanced cow top sirloin butt and strip loin steaks were significantly less tender for first impression and overall tenderness than enhanced cow and USDA Select steaks ($P < 0.05$) over both aging periods (14 and 28 d). Table 4 also shows that the non-enhanced cow top sirloin butt and strip loin steaks had significantly more connective tissue ($P < 0.05$). These data were supported by an earlier study conducted by Hunsley et al. (1971), which reported that the protein content of the connective tissue residue increased as the age of the animal increased. Aging period was also significant for strip loin steaks for first impression tenderness and connective tissue amount. Least squares means for 28 d aged steaks for first impression tenderness (5.49 ± 0.15 vs. 5.28 ± 0.15) were significantly higher ($P < 0.05$) indicating that the steaks were more tender than 14 d aged steaks (data not presented in tabular form). Connective tissue amount was significantly higher ($P < 0.05$) for 28 d aged steaks as compared to 14 d aged steaks (6.08 ± 0.16 vs. 5.89 ± 0.16) indicating that 28 d were rated as having less connective tissue than 14 d steaks across all treatments (data not presented in tabular form).

Data presented in Table 5 displays the least square means for intensity of flavor attributes of ribeye steaks by treatment over both aging periods (14 and 28 d). Least squares means for intensity of beef flavor were significantly different between all treatments ($P < 0.05$); Select and non-enhanced cow ribeye steaks had more beef flavor than enhanced cow ribeye steaks (Table 5). In addition, enhanced cow ribeye steaks were significantly more salty ($P < 0.05$) and had greater presence of a soapy off flavor than non-enhanced cow and USDA Select steaks. The significance of salt intensity in enhanced cow steaks is supported by a previous study on enhanced beef verus non-enhanced beef product where researchers stated that enhanced beef was significantly more salty than the controls (Robbins et al., 2003a). The treatment by age interaction was significant for painty/fishy and grassy/cow flavors in ribeye steaks. Non-enhanced cow ribeye steaks at 28 d and enhanced cow and USDA Select steaks at 14 d were rated as having a more intense ($P < 0.05$) painty/fishy flavor than non-enhanced cow ribeye steaks aged for 14 d (Table 6). Non-enhanced 28 d aged ribeye steaks had a more intense ($P <$ 0.05) grassy/cow off flavor when compared to all other treatment by age interaction groups (Table 6). Select ribeye steaks at 14 and 28 d of age had a less intense grassy/cow off flavor when compared to non-enhanced cow 28 d age and enhanced cow 28 d age ribeye steaks.

Strip loin steak sensory data indicated a treatment group effect for flavor intensity for beef flavor, salty flavor, and painty/fishy flavor over both aging periods (14 and 28 d; Table 7). Beef flavor intensity was significantly different ($P < 0.05$) between all treatment groups with USDA Select having the most beef flavor followed by non-enhanced cow strip loin steaks and enhanced cow strip loin steaks. Strip loin steaks were rated as ribeye steaks for intensity of salty flavor, with enhanced cow strip loin steaks being more salty ($P < 0.05$) than the other two treatment groups (Table 7). Non-enhanced cow strip loin steaks had a more intense ($P < 0.05$) painty/fishy flavor as compared to enhanced cow and Select strip loin steaks (Table 7). Data show that the intensity of flavor for 28 d aged strip loin steaks was significantly higher ($P < 0.05$) and also had a more intense painty/fishy off flavor than 14 d aged strip loin steaks (data not presented in tabular form). The treatment by age interaction was significant for the intensity of grassy/cow flavor in strip loin steaks. Data shows that enhanced cow 28 d steaks were significantly higher intensity ($P < 0.05$) when compared to the other treatments and age groups. Table 8 shows that USDA Select steaks and non-enhanced cow at 14 d were significantly lower ($P < 0.05$) grassy/cow off flavor than the enhanced cow at both aging periods and non-enhanced cow steaks at 28 d.

Data show that enhanced cow top sirloin butt steaks were significantly lower ($P < 0.05$) in beef flavor (1.54 ± 0.11) than non-enhanced cow and USDA Select top sirloin butt steaks. Aging period was also significant for beef flavor and painty/fishy flavor in top sirloin butt steaks. Beef flavor intensity was lower ($P < 0.05$) at 28 d of age than at 14 d of age across all treatment groups. Intensity of painty/fishy flavor was higher ($P < 0.05$) at 28 d of age as compared to 14 d of age (1.23 ± 0.05 vs. 1.13 ± 0.04). Grassy/cowy flavor intensity means were also significantly higher ($P < 0.05$) for top sirloin steaks at 28 d (1.89 ± 0.08 vs. 1.23 ± 0.07; data not presented in tabular form). The treatment by age interaction was significant for salt intensity in top sirloin butt steaks. The intensity of salt flavor in enhanced cow top sirloin butt steaks was higher ($P < 0.05$) at 14 d of age and at 28 d of age as compared to all other treatment by age groups. These results were supported by a previous study that found that enhanced beef had significantly higher salty flavor due to the salt/phosphate enhancement solution (Robbins et al., 2003a). In another study investigating three levels of NaCl in an enhancement solution, revealed that the intensity of a salty flavor increased significantly when injected into *biceps femoris and infraspinatus* steaks (Baublits et al., 2006). Table 9 shows that there was no significant difference in salt intensity ($P > 0.05$) when comparing non-enhanced cow and USDA Select top sirloin butt steaks at either aging period (14 or 28 d). Table 9 also shows that there was no significant difference ($P > 0.05$) in soapy intensity between treatments at any aging period for top sirloin butt steaks.

Color Evaluation

The treatment by age interaction was significant for muscle color, surface discoloration, and overall appearance for ribeye and strip loin steaks. Select ribeye and strip loin steaks had the brightest cherry-red color ($P < 0.05$) at 14 d as compared to Select steaks at 21 and 28 d of age, as well as enhanced cow and non-enhanced cow at all aging periods (14, 21, or 28 d). Table 10 shows that enhanced and non-enhanced cow ribeye steaks at 21 and 28 d of age had the darkest red muscle color therefore possessing the lowest overall appearance. Enhanced cow ribeye steaks at 21 d of age had the least amount of surface discoloration ($P < 0.05$) as compared to non-enhanced cow ribeye steaks aged for 21 and 28 d and USDA Select ribeye steaks aged for14 d, which had the most surface discoloration. Select strip loin steaks at 14 d of age, just as with ribeye steaks, had the brightest cherry-red muscle color ($P < 0.05$) and the highest overall appearance as compared to all other treatment by age interaction groups. This is supported by results from a previous study looking at enhancement solutions with different levels of NaCl, the LM muscle maintained better color than the other two muscle types during display (Baublits et al., 2006). Enhanced cow strip loin steaks at 21 d of age had the darkest red muscle color and the lowest overall appearance as compared to all other treatments and aging periods. Select strip loins at 28 d had the highest amount of surface discoloration ($P < 0.05$). Select strip loin steaks at 14 d of age and enhanced cow strip loin steaks at 14 and 21 d of age had the least surface discoloration.

Muscle color was significant by treatment over all aging periods (14, 21, and 28 d) for top sirloin butt steaks (Table 11). Select top sirloin butt steaks had the brightest cherry-red muscle color (*P* < 0.05) as compared to all other treatments, and enhanced cow top sirloin butt steaks had the darkest muscle color (*P* < 0.05). In a study investigating the utility of lactate and rosemary in beef enhancement solutions and the effects of color changes during display, results revealed that steaks injected up to 6% with rosemary and lactate solution (0.25 % salt, 0.28% phosphate, 1.5% lactate, and 484 ppm rosemary) or a lactate solution (0.25 % salt, 0.28% phosphate, 1.5% lactate) were darker in muscle color when compared to steaks injected with rosemary solution 0.25% salt, 0.28% phosphate, 708 ppm rosemary; Mancini et al., 2005. Top sirloin steaks at 21 d of age had a brighter (*P* < 0.05) red color than 14 d age steaks (2.95 ± 0.07 vs. 2.64 ± 0.06) while top sirloin steaks at 28 d of age had the darkest red color (2.34 ± 0.07; data not presented in tabular form). Furthermore, these data aligned with results reported by Hutchison (2007), revealing that the cow steaks aged for 28 d were less color stable than steaks aged for 7 d.

Treatment group was significant for L* and b* values in ribeye and strip loin steaks over all aging periods. Select steaks had the highest L* values (*P* < 0.05) as well as the highest b* value (*P* < 0.05) in ribeye and strip loin steaks. While L* and b* were similar in enhanced cow and non-enhanced cow ribeye steaks, non-enhanced cow strip loin steaks were brighter and had a higher b* value than enhanced cow strip loin steaks (Table 12). These results do not agree with a previous study looking CaCl injected steaks, where all the CaCl injected steaks showed higher b* values than any of the other treatments in that study (Harris et al., 2001). In addition, ribeye steaks at 28 d of age overall all treatment groups had the lowest (*P* < 0.05) b* value (13.16 ± 1.12). At 14 and

21 d of age, there was no significant difference in b* values ($P > 0.05$). Strip loin steaks had a significant difference in b* by age over all treatments. At 14 d of age, strip loin steaks had the highest b* value when compared to 21 d aged steaks (15.93 ± 0.21 vs. 15.34 ± 0.22); and b* at 21 d of age was higher ($P < 0.05$) than the b* value at 28 d of age (15.34 ± 0.22 vs. 14.51 ± 0.23; data not presented in tabular form). The treatment by age interaction was significant for a* values in strip loin steaks. Enhanced cow, non-enhanced cow, and USDA Select strip loin steaks at 14 d of age were redder ($P < 0.05$) in the color as compared to all treatments at 21 and 28 d of age. Select strip loin steaks at 28 d of age had the lowest a* value ($P < 0.05$) than all other treatment by age interaction groups (Table 13).

Aging period was significant for top sirloin butt steaks over all treatment groups. While there was no difference between 14 and 21 d aged steaks, 28 d aged steaks were darker than 14 and 21 d aged steaks (data not presented in tabular form). The treatment by age interaction was significant for b* values in top sirloin butt steaks (Table 14). Select top sirloin butt steaks at 14, 21, 28 d of age had higher b* values than all other treatment by age interaction groups, while enhanced top sirloin butt steaks at 14, 21, and 28 d of age had the lowest ($P < 0.05$) b* values of all treatment by age interaction groups. There was no significant difference in the a* value in top sirloin butt steaks by treatment, age or the treatment by age interaction.

Surface discoloration for top sirloin butts was significant by treatment (Table 15). Non-enhanced cow top sirloin butts displayed the highest percentage ($P < 0.05$) surface discoloration. This was supported by data from a previous study that showed that heifers fed no vitamin E and not injected with CaCl had the highest of surface discoloration that the steaks injected with CaCl (Harris et al., 2001). Enhanced cow top sirloin butts had the lowest percentage ($P < 0.05$) of surface discoloration when compared to non-enhanced cow and USDA Select top sirloin butts. Surface discoloration was also significant for the different aging periods on top sirloin butts. Top sirloin butts steaks, aged for 28 d, displayed the highest surface discoloration ($P < 0.05$), while 21 d aged steaks displayed the lowest (Table 16).

These data from this research indicate that the enhanced cow steaks were comparable to USDA Select steaks from a tenderness and juiciness standpoint. When compared to non-enhanced cow product, the enhanced product was less tender and drier. Non-enhanced cow product possessed the highest cook loss. The enhanced cow product was dark in color and revealed undesirable off flavors such as an intense score for soapy and salty. Grassy/cow and metallic off flavors were less intense than the non-enhanced cow product, but were still detected from a sensory standpoint. There should be more research conducted to improve the effects of enhancement solutions on color.

IMPLICATIONS

This study has shown by enhancing cow subprimals, tenderness was improved when compared to non-enhanced cow and USDA Select subprimals. Enhanced cow subprimals were juicier than the non-enhanced cow and USDA Select subprimals but had undesirable off flavor characteristics. Enhanced cow subprimals were the darkest in color and had the lowest L*, a*, and b* values. These data show that there needs to be further research to refine and develop solutions for this application to improve their influence on color stability and prolonged shelf life of enhanced cow subprimals. Furthermore, research needs to be conducted to investigate antemortem practices such as grain supplementation that could improve the negative characteristics of mature cow meat with postmortem enhanced subprimals. Mature cow meat could be competitive with USDA Select subprimals but improvements need to be made to mask off flavors and the negative effects on color associated with the enhancement process.

Table 1. Least squares (LS) means for Warner-Bratzler Shear Force (WBSF) and cook loss for ribeyes and top sirloin butts (n = 20 subprimals per treatment) treatment stratified by aging period.

Product Group	Treatment	Age	WBS	WBS SEM	Cook Loss	Cook Loss SEM
Ribeyes	Enhanced Cow	14	3.50[ef]	0.27	18.41[c]	0.64
		21	3.49[ef]	0.27		
		28	3.35[e]	0.27		
	Non-enhanced Cow	14	6.03[b]	0.27	25.76[a]	0.64
		21	7.04[a]	0.27		
		28	5.09[c]	0.27		
	USDA Select	14	4.48[cd]	0.27	22.99[b]	0.63
		21	4.16[de]	0.27		
		28	4.00[def]	0.27		
Top Sirloin Butts	Enhanced Cow	14	3.97[b]	0.26	17.30[c]	0.72
		21	4.52[b]	0.26		
		28	4.28[b]	0.26		
	Non-enhanced Cow	14	5.29[a]	0.26	24.18[a]	0.72
		21	4.42[b]	0.26		
		28	5.50[a]	0.26		
	USDA Select	14	4.60[b]	0.26	20.85[b]	0.72
		21	4.13[b]	0.26		
		28	4.18[b]	0.26		

[a,b,c,d,e,f] LS means with the same letter in the same column are not different (P > 0.05).

Table 2. Least squares (LS) means for Warner-Bratzler Shear Force (WBSF) and cook loss for strip loins (n = 20 subprimals per treatment) by treatment over all aging periods (14, 21, 28 d).

Treatment	WBS	WBS SEM	Cook Loss	Cook Loss SEM
Non-enhanced Cow	4.58[a]	0.15	20.70[a]	0.69
Enhanced Cow	3.90[b]	0.14	14.32[c]	0.68
USDA Select	3.09[c]	0.14	15.01[b]	0.68

[a,b,c] LS means in the same column with different letters are different ($P < 0.05$).

Table 3. Least squares (LS) means for sensory by treatment for juiciness on ribeyes, strip loins, and top sirloin butts (n = 20 subprimals per treatment) over all aging periods (14 and 28 d).

Product	Treatment	Initial Juiciness[1]	SEM	Sustained Juiciness[2]	SEM
Ribeyes	Enhanced Cow	5.73[a]	0.16	6.00[a]	0.15
	Non-enhanced Cow	4.61[b]	0.16	4.80[b]	0.14
	USDA Select	4.76[b]	0.16	4.96[b]	0.14
Strip Loins	Enhanced Cow	5.53[a]	0.14	5.68[a]	0.15
	Non-enhanced Cow	4.92[b]	0.14	5.09[b]	0.15
	USDA Select	4.40[c]	0.14	4.55[c]	0.15
Top Sirloin Butts	Enhanced Cow	5.23[a]	0.18	5.39[a]	0.17
	Non-enhanced Cow	4.37[b]	0.14	4.46[b]	0.14
	USDA Select	4.09[b]	0.14	4.20[b]	0.14

[a,b,c] LS Means with the same letter in the same column are not different (P > 0.05).
[1,2] Juiciness: 1 = extremely dry, 8 = extremely juicy.

Table 4. Least square (LS) means for sensory by treatment for tenderness and connective tissue amount on ribeyes, strip loins, and top sirloin butts (n = 20 subprimals per treatment) over all aging periods (14 and 28 d).

Product	Treatment	Tenderness First Impression[1]	SEM	Tenderness Overall Impression[2]	SEM	Connective Tissue Amount[3]	SEM
Ribeyes	Enhanced Cow	5.98[a]	0.14	6.06[a]	0.13	6.25[a]	0.12
	Non-enhanced Cow	4.30[c]	0.14	4.54[b]	0.13	5.03[b]	0.12
	USDA Select	5.66[b]	0.14	5.82[a]	0.13	6.44[a]	0.12
Strip Loins	Enhanced Cow	5.71[a]	0.16	5.75[a]	0.15	6.05[a]	0.17
	Non-enhanced Cow	4.88[b]	0.16	4.95[b]	0.15	5.48[b]	0.16
	USDA Select	5.57[a]	0.16	5.72[a]	0.15	6.42[a]	0.16
Top Sirloin Butts	Enhanced Cow	5.30[a]	0.18	5.33[a]	0.17	5.45[b]	0.24
	Non-enhanced Cow	4.32[b]	0.15	4.40[b]	0.15	4.88[c]	0.22
	USDA Select	4.98[a]	0.15	5.11[a]	0.15	5.77[a]	0.22

[a,b,c] LS Means with the same letter in the same column are not different (P > 0.05).
[1,2] Tenderness: 1 = extremely tough, 8 = extremely tender..
[3] Connective tissue: 1 = abundant, 8 = none.

Table 5. Least squares (LS) means for sensory by treatment for intensity of flavor attributes on ribeyes (n = 20 subprimals per treatment) over all aging periods (14 and 28 d).

Treatment	Beef[1]		SEM	Salty[2]		SEM	Soapy[3]		SEM
Enhanced Cow	1.98[c]	±	0.09	1.82[a]	±	0.06	1.14[a]	±	0.02
Non-enhanced Cow	2.19[b]	±	0.09	1.02[b]	±	0.06	1.04[b]	±	0.02
USDA Select	2.35[a]	±	0.09	1.04[b]	±	0.06	1.02[b]	±	0.02

[a,b,c] LS Means with the same letter in the same column are not different ($P > 0.05$).
[1,2,3] Flavor intensity: 1 = not detectable, 3 = strongly detectable.

Table 6. Least squares (LS) means for sensory by treatment and by age for intensity of flavor attributes on ribeyes (n = 20 subprimals per treatment).

Treatment	Age	Painty/Fishy[1]	SEM	Grassy/Cowy[2]	SEM
Enhanced Cow	14	1.11[ab]	0.05	1.18[bc]	0.05
	28	1.07[b]	0.05	1.31[b]	0.05
Non-enhanced Cow	14	1.09[b]	0.05	1.22[bc]	0.05
	28	1.18[a]	0.05	1.48[a]	0.05
USDA Select	14	1.11[ab]	0.05	1.11[c]	0.05
	28	1.08[b]	0.05	1.10[c]	0.05

[a,b,c] LS Means with the same letter in the same column are not different ($P > 0.05$).
[1,2] Flavor intensity: 1 = not detectable, 3 = strongly detectable.

Table 7. Least squares (LS) means for sensory by treatment for intensity of flavor attributes on strip loins (n = 20 subprimals per treatment) over all aging periods (14 and 28 d).

Treatment	Beef[1]	SEM	Salty[2]	SEM	Painty/Fishy[3]	SEM
Enhanced Cow	1.86[c]	0.11	1.89[a]	0.05	1.08[b]	0.04
Non-enhanced Cow	2.23[b]	0.11	1.01[b]	0.05	1.14[a]	0.04
USDA Select	2.43[a]	0.11	1.03[b]	0.05	1.08[b]	0.04

[a,b,c] LS Means with the same letter in the same column are not different (P > 0.05).
[1,2,3] Flavor intensity: 1 = not detectable, 3 = strongly detectable.

Table 8. Least square (LS) means for sensory by treatment stratified by aging period (14 and 28 d) for intensity of flavor attributes on strip loins (n = 20 subprimals per treatment).

Treatment	Age	Grassy/Cowy[1]	SEM
Enhanced Cow	14	1.41[b]	0.08
	28	1.42[a]	0.08
Non-enhanced Cow	14	1.13[c]	0.08
	28	1.39[b]	0.08
USDA Select	14	1.11[c]	0.08
	28	1.11[c]	0.08

[a,b,c] LS Means with the same letter in the same column are not different ($P > 0.05$).
[1] Flavor intensity: 1 = not detectable, 3 = strongly detectable.

Table 9. Least squares (LS) means for sensory by treatment stratified by aging period (14 and 28 d) for intensity of flavor attributes on top sirloin butts (n = 20 subprimals per treatment).

Treatment	Age	Salty[1]	SEM	Soapy[2]	SEM
Enhanced Cow	14	1.89[a]	0.05	1.03	0.01
	28	1.34[b]	0.1	1.00	0.03
Non-enhanced Cow	14	1.00[c]	0.05	1.00	0.01
	28	1.00[c]	0.07	1.03	0.02
USDA Select	14	1.00[c]	0.05	1.01	0.02
	28	1.00[c]	0.07	1.02	0.02

[a,b,c] LS Means with the same letter in the same column are the same (P > 0.05).
[1] Flavor intensity: 1 = not detectable, 3 = strongly detectable.
[2] Treatment, Age, or Treatment *age not significant.

Table 10. Least squares (LS) means for color evaluation by treatment (n = subprimals per treatment) stratified by aging period (14, 21, and 28 d) for muscle color, surface discoloration, and overall appearance on ribeyes and strip loins.

Product	Treatment	Age	Muscle Color[1]	Muscle Color SEM	Surface Discoloration[2]	Surface Discoloration SEM	Overall Appearance[3]	Overall Appearance SEM
Ribeyes	Enhanced Cow	14	3.17^{c}	0.12	2.43^{c}	0.14	3.21^{a}	0.11
		21	2.32^{d}	0.11	2.16^{d}	0.12	2.51^{b}	0.09
		28	2.03^{d}	0.15	3.00^{b}	0.20	2.20^{b}	0.16
	Non-enhanced Cow	14	3.54^{b}	0.12	2.98^{b}	0.14	3.41^{a}	0.11
		21	2.36^{d}	0.11	3.77^{a}	0.12	2.38^{b}	0.09
		28	2.16^{d}	0.15	3.68^{a}	0.20	2.08^{b}	0.16
	USDA Select	14	4.09^{a}	0.11	3.45^{a}	0.13	3.43^{a}	0.10
		21	3.44^{bc}	0.11	2.80^{b}	0.12	3.32^{a}	0.09
		28	3.37^{bc}	0.12	2.74^{bc}	0.13	3.37^{a}	0.10
Strip Loins	Enhanced Cow	14	2.83^{cd}	0.15	2.54^{e}	0.10	3.06^{c}	0.12
		21	2.47^{d}	0.15	2.52^{e}	0.12	2.59^{d}	0.13
		28	1.67^{e}	0.16	2.86^{cd}	0.12	1.79^{e}	0.13
	Non-enhanced Cow	14	3.52^{bc}	0.15	2.63^{d}	0.10	3.60^{b}	0.12
		21	2.98^{c}	0.16	3.08^{c}	0.12	2.93^{c}	0.13
		28	2.32^{d}	0.16	2.98^{c}	0.12	2.47^{d}	0.13
	USDA Select	14	4.23^{a}	0.15	2.56^{e}	0.10	4.05^{a}	0.12
		21	3.35^{bc}	0.16	3.46^{b}	0.12	3.10^{c}	0.13
		28	3.54^{b}	0.16	3.92^{a}	0.14	3.22^{c}	0.14

^{a,b,c,d} LS Means with the same letter in the same column are the same (P > 0.05).
[1] Muscle Color: 1 = extremely dark red, 8 = extremely bright cherry red.
[2] Surface Discoloration: 1 = no discoloration, 7 = total discoloration.
[3] Overall Appearance: 1 = extremely undesirable, 8 = extremely desirable.

Table 11. Least squares (LS) means for color evaluation by treatment (n = 20 subprimals per treatment) for muscle color on top sirloin butts over all aging periods (14, 21, 28 d).

Treatment	Muscle Color[1]	Muscle Color SEM
Enhanced Cow	1.84[c]	0.06
Non-enhanced Cow	2.45[b]	0.06
USDA Select	3.63[a]	0.06

[a,b,c] LS Means with different letters in the same column are different ($P < 0.05$).
[1] Muscle Color: 1 = extremely dark red, 8 = extremely bright cherry red.

Table 12. Least squares (LS) means for color evaluation by treatment (n = 20 subprimals per treatment) for L* and b* values on ribeyes and strip loins over all aging periods (14, 21, 28 d).

Product	Treatment	L*[1]	L* SEM	b*[2]	b* SEM
Ribeyes	Enhanced Cow	32.85[b]	1.40	13.89[b]	0.98
	Non-enhanced Cow	34.08[b]	1.40	14.91[b]	0.98
	USDA Select	39.42[a]	1.11	18.02[a]	0.78
Strip Loins	Enhanced Cow	32.82[c]	.49	14.14[c]	0.22
	Non-enhanced Cow	36.61[b]	.49	15.18[b]	0.22
	USDA Select	41.41[a]	.49	16.46[a]	0.23

[a,b,c] LS Means with the same letter in the same column are the same (P > 0.05).
[1] L*= luminosity; where 0=Black, 100= white.
[2] b*= yellowness; where negative values = blue, positive values = yellow.

Table 13. Least square (LS) means for color evaluation by treatment (n = 20 subprimals per treatment) and by age for a* values on strip loins.

Treatment	Age	a*[1]	a* SEM
Enhanced Cow	14	18.54[a]	0.38
	21	16.66[b]	0.40
	28	15.47[c]	0.40
Non-enhanced Cow	14	18.90[a]	0.36
	21	16.39[bc]	0.39
	28	16.13[bc]	0.39
USDA Select	14	18.29[a]	0.36
	21	16.42[bc]	0.39
	28	13.25[d]	0.43

[a,b,c,d] LS Means with the same letter in the same column are the same ($P > 0.05$).
[1] a* = redness; where negative values = green, positive values = red.

Table 14. Least square (LS) means for color evaluation by treatment (n = 20 subprimals) and by age for a* and b* values on top sirloin butts.

Treatment	Age	a*[1,2]	a* SEM	b*[3]	b* SEM
Enhanced Cow	14	16.32	1.34	12.53[d]	0.21
	21	14.71	1.66	12.28[d]	0.24
	28	14.13	1.66	12.38[d]	0.24
Non-enhanced Cow	14	14.47	1.34	13.42[c]	0.21
	21	14.77	1.66	14.30[b]	0.24
	28	18.76	1.66	13.90[bc]	0.24
USDA Select	14	15.92	1.34	16.05[a]	0.21
	21	15.87	1.66	15.87[a]	0.24
	28	15.28	1.66	16.36[a]	0.24

[a,b,c,d] LS Means with the same letter in the same column are the same ($P > 0.05$).
[1] Traits (Treatment, Age, and Treatment by age interaction) are not significant.
[2] a* = redness; where negative values = green, positive values = red.
[3] b* = yellowness; where negative values = blue, positive values = yellow.

Table 15. Least square (LS) means for surface discoloration of top sirloin butts by treatment (n = 20 subprimals per treatment).

Treatment	Surface Discoloration[1]	Surface Discoloration SEM
Non-enhanced Cow	3.22[a]	0.08
USDA Select	3.14[a]	0.08
Enhanced Cow	2.71[b]	0.08

[a,b] LS Means with the same letter in the same column are the same (P > 0.05).
[1] Surface Discoloration: 1 = 0% discoloration; where 7 = 100% discoloration.

Table 16. Least Square (LS) means for surface discoloration on top sirloin butts (n = 20 subprimals per treatment) over all aging periods (14, 21, 28 d).

Aging Period	Surface Discoloration[1]	Surface Discoloration SEM
28 d	3.39[a]	0.09
14 d	3.01[b]	0.05
21 d	2.67[c]	0.09

[a,b,c] LS means with different letters in the same column are different ($P < 0.05$).
[1]Traits for Surface discoloration: 1 = 0% discoloration; where 7 = 100% discoloration.

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APPENDIX

Appendix A

OSU Meat Color Score Sheet

Evaluator: ____________ **Project:** Cow subprimals **Date:** ____________ **AM / PM**

Sub: Ribeye **Age:** 21d

Muscle Color (MC)

8 Extremely bright cherry red
7 Bright cherry red
6 Moderately bright cherry red
5 Slightly bright cherry red
4 Slightly dark cherry red
3 Moderately dark cherry red
2 Dark red
1 Extremely dark red

Surface Discoloration (SD)

7 Total Discoloration (100%)
6 Extensive discoloration (80-99%)
5 Moderate discoloration (60-79%)
4 Modest discoloration (40-59%)
3 Small discoloration (20-39%)
2 Slight discoloration (1-19%)
1 No discoloration (0%)

Overall Appearance (OA)

8 Extremely desirable
7 Very desirable
6 Moderately desirable
5 Slightly desirable
4 Slightly undesirable
3 Moderately undesirable
2 Very undesirable
1 Extremely undesirable

ID	MC	SD	OA	ID	MC	SD	OA	ID	MC	SD	OA
1				21				41			
2				22				42			
3				23				43			
4				24				44			
5				25				45			
6				26				46			
7				27				47			
8				28				48			
9				29				49			
10				30				50			
11				31				51			
12				32				52			
13				33				53			
14				34				54			
15				35				55			
16				36				56			
17				37				57			
18				38				58			
19				39				59			
20				40				60			

Appendix B

Trained Taste Panel Sheet

Panelist No. ________ Date: ________________ Time: ____________________

Sample	Initial Juiciness	Sustained Juiciness	Tenderness (First Impression)	Tenderness (Overall Impression)	Connective Tissue	Cooked Beef Flavor	Salty Flavor	Soapy Flavor	Painty / Fishy	Grassy / Cowy

Initial and Sustained Juiciness		Tenderness		Connective Tissue Amount		Beef/Salty/Soapy/Painty-Fishy/Grassy-Cowy	
8	Extremely Juicy	8	Extremely Tender	8	None	3	Strong
7	Very Juicy	7	Very Tender	7	Practically None	2	Slightly Detectable
6	Moderately Juicy	6	Moderately Tender	6	Traces	1	Not Detectable
5	Slighty Juicy	5	Slightly Tender	5	Slight		
4	Slighty Dry	4	Slightly Tough	4	Moderate		
3	Moderately Dry	3	Moderately Tough	3	Slightly Abundant		
2	Very Dry	2	Very Tough	2	Moderately Abundant		
1	Extremely Dry	1	Extremely Tough	1	Abundant		

Appendix C

Oklahoma State University Institutional Review Board

Date	Thursday, August 09, 2007	**Protocol Expires:**	**1/10/2008**
IRB Application	AG071		
Proposal Title:	Comparison of Tenderness, Palatability, and Retail Caselife of Enhanced Cow Subprimals to Control Cow and USDA Select Subprimals		

Reviewed and Processed as: Exempt

Modification

Status Recommended by Reviewer(s) **Approved**

Principal Investigator(s) :

Deborah VanOverbeke 104D An. Sci. Stillwater, OK 74078	Mindy Rose 108 ANSI Stillwater, OK 74078	Gretchen Hilton 104A Animal Science Stillwater, OK 74078

The requested modification to this IRB protocol has been approved. Please note that the original expiration date of the protocol has not changed. The IRB office MUST be notified in writing when a project is complete. All approved projects are subject to monitoring by the IRB

☒ 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.

Signature : Sue C Jacobs

Sue C. Jacobs, Chair, OSU Institutional Review Board

Thursday, August 09, 2007
Date

VITA

Mindy Nicole Rose

Candidate for the Degree of

Master of Science

Thesis: COMPARISON OF TENDERNESS, PALATABILITY, AND RETAIL CASELIFE OF ENHANCED SUBPRIMALS TO CONTROL COW AND USDA SELECT SUBPRIMALS

Major Field: Animal Science

Biographical:

Personal Data: Born in Cottage Grove, Oregon on April 2, 1985, the daughter of Michael and Tamma Rose.

Education: Graduated from Elkton High School, Elkton, Oregon in May 2003; received a Bachelor of Science degree in Animal Science from Oregon State University, Corvallis, Oregon in June 2007; Completed the requirements for the Master of Science in Animal Science at Oklahoma State University, Stillwater, Oklahoma in December, 2008.

Experience: Raised outside of Elkton, Oregon on a family farm with parents who placed emphasis upon responsibility and continual education. Employed by Oregon State University, Department of Animal Science 2003 – 2007; Oklahoma State University, Department of Animal Science 2005 – 2006; and Oklahoma State University as a graduate research assistant, 2007 to present.

Professional Memberships: American Meat Science Association

Name: Mindy Rose
Date of Degree: December 2008
Institution: Oklahoma State University
Location: Stillwater, Oklahoma

Title of Study: COMPARISON OF TENDERNESS, PALATABILITY, AND RETAIL CASELIFE OF ENHANCED SUBPRIMALS TO CONTROL COW AND USDA SELECT SUBPRIMALS

Pages in Study: 58
Candidate for the Degree of Master of Science

Major Field: Animal Science

The objective of this study was to determine the impact of enhancement of cow subprimals on tenderness, palatability, and retail caselife as compared to control cow subprimals and USDA Select subprimals. The data from this research project proved that the enhanced cow steaks were comparable to USDA Select steaks from a tenderness and juiciness standpoint when compared to non-enhanced cow product. However when comparing the enhanced cow product from a color evaluation standpoint, there should be more research conducted to improve the effects of enhancement solution on color.

ADVISER'S APPROVAL: Dr. Gretchen Hilton