APPLICATIONS OF THE SUSPENTEC® SYSTEM IN IMPROVING BEEF ROUND PALATIBILITY

By

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APPLICATIONS OF THE SUSPENTEC® SYSTEM IN

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CHAPTER I

INTRODUCTION

Tenderness is one of the most sought after palatability characteristics from a consumer standpoint in both the home and restaurant. The beef industry as a whole strives to produce a highly palatably and consistent end product. Following the last National Beef Tenderness Survey (National Cattlemans Beef Association, 2005), it became apparent that the industry has improved tenderness traits from past years; however, focus on cuts derived from the round are imperatively behind those from the chuck and loin. According to the USDA boxed beef market prices, round cuts are in the bottom 25% in terms of value, therefore, it is evident that the industry would benefit from value added round cuts. This would not only increase palatability characteristics of these cuts, but will allow the consumer to purchase a cheaper product and gain a more pleasant eating experience.

Boleman et al. (1997) found that consumers are willing to pay a premium for steaks with known increased tenderness scores. This implies that potential revenue is to be gained especially within the sector of potentially known “tough” products such as round cuts if tenderness can be improved. Value added round cuts have inherent significance to be sold among food service sectors throughout the industry, not only increasing the revenue of these restaurateurs but enhancing the consumers' overall eating experience.

CHAPTER II

REVIEW OF LITERATURE

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

Tenderness is one of the most important palatability attributes to consumers. According to Miller et al. (2001), the beef industry produces 15 to 20% tough steaks that are sold to consumers. Miller et al. (2001) also showed that consumers could differentiate between steaks of different Warner-Bratzler shear force levels and were willing to pay a higher price for steaks that were more tender of the same USDA quality grade. However, when steaks become tougher, flavor and juiciness have a greater effect on consumer satisfaction.

Shackelford et al. (1995) found a very weak relationship between peak load and overall tenderness in *semitendinosus* (ST) and *biceps femoris* (BF) with r-values of 0.23 and 0.06, respectively. Additionally, they reported significant correlations with overall tenderness and juiciness ($r = 0.59$; $P < 0.05$) and connective tissue ($r = 0.78$; $P < 0.001$) in the BF; however, no significant correlations were observed among these traits in the ST (Shackelford et al., 1995).

In a study completed by Miller et al. (1995), 22 BF, ST and longissimus steaks were evaluated for tenderness by consumers in home and in a restaurant setting. Consumers in the restaurant setting found a significantly higher percentage of acceptable product than consumers in their homes. Miller et al. also found that the correlation coefficients between tenderness acceptability and overall acceptability in the home and in the restaurant were 0.66 and 0.73, respectively. Furthermore, results demonstrated that tenderness only accounted for 44% of the variation in overall acceptability in the home and 53% in the restaurant (Miller et al., 1995). Despite the fact that tenderness plays the largest role in consumer overall acceptability, juiciness and flavor play major roles as well.

Destefanis et al. (2008) provided consumers with *longissimus thoracis* samples in order to evaluate their ability to distinguish differences in tenderness from five known tenderness categories according to WBS values. It was reported that consumers had some difficulty in discriminating very tough from tough steaks, likewise with very tender from tender steaks; however, consumers could easily ($P < 0.05$) distinguish tenderness when steaks were broken into three groups tough, intermediate, and tender. It was concluded that consumers perceived beef with WBS values > 5.37 kg as tough and those < 4.37 kg as tender (Destefanis et al., 2007). This indicates that though consumers may not be able to determine tenderness as precisely as WBS variation can be detected.

Relationship between lipid oxidation and beef flavor

Campo et al. (2006) reported that lipid oxidation is a major factor affecting meat quality. Thiobarbituric acid reactive substances (TBARS) and sensory panels were conducted on product that was subjected to a wide range of potential oxidation by altering the polyunsaturated fatty acid (PUFA) composition and by displaying the meat in high oxygen modified atmosphere packaging for varying lengths of time. There was a significant ($P < 0.001$) correlation (r = 0.84) between TBARS and the perception of rancidity in these cuts. Additionally, panelists' preferences were significantly ($P < 0.001$) related to the presence of beef flavor, the absence of abnormal flavors, and rancidity off flavors (r = 0.93, 0.88, and 0.83, respectively). Campo et al. (2006) found that a TBARS value (as expressed as mg of malonaldehyde/kg of lean muscle) of 2.0 could be considered the limiting point when rancid flavor overpowers beef flavor and should be considered the maximum acceptable level for positive sensory perception of beef.

Greene and Cumuze (1981) conducted a study evaluating the correlation between sensory scores and TBARS with inexperienced panelists and found that flavor scores from all consumer panel groups were correlated ($P < 0.01$) with TBARS numbers, although the correlations were relatively weak (r = 0.16 to 0.32). The discriminating panelists had significantly ($P < 0.01$) higher correlations to off flavors with coefficients ranging from 0.44 – 0.53. Greene and Cumuze (1981) also determined that the flavor detection threshold among inexperienced panelists varied from group to group; however, a TBARS ranging from 0.6 to 2.0 would represent the initial differentiation of the discriminating panelists.

Palatability and tenderness ratings of round cuts in beef

Results from the 2005 National Beef Tenderness Survey (NCBA, 2005) indicated that tremendous progress has been made in terms of tenderness in virtually all major marketable cuts since the 1999 survey, with an approximately 18% increase in tenderness. This survey encompassed 82 retail outlets in major cities from coast to coast. Although there was variation in thickness from cut to cut, round steaks demonstrated the highest average WBS values, specifically the eye of round and bottom round flat with means of 7.5 and 8.1 lbs, respectively (NCBA, 2005). Within bottom round steaks, 22% of steaks collected were very tender, 48.2% were tender, 18.5% were intermediate, and 11.1% were classified as tough according to WBS values. A higher percentage of eye of round steaks were classified as tender (55.2%), while a much lower percent were deemed tough (3.5%). Consumers rated bottom round and eye of round steaks lower ($P < 0.05$) in overall acceptability when compared to the other cuts in the survey. Furthermore, consumer panelists ranked these cuts lower in juiciness, tenderness, and overall flavor than the other cuts surveyed. These results indicate that round cuts require more postmortem attention to ensure acceptable tenderness (NCBA, 2005).

While attempting to map intramuscular tenderness variation in round cuts, Reuter et al. (2002) found that WBS values varied greatly depending on location within the *biceps femoris*, but shear values were relatively uniform within the ST. Additionally Reuter et al. (2002) found that the BF shear force values were lowest at the origin (sirloin end), intermediate at the insertion, and the highest WBS values were in the middle of the subprimal ($P < 0.05$) with mean values ranging form 2.80 to 5.63 kg from the sirloin end to the middle and 3.91 to 5.62 kg from the middle to insertion. These results suggest that alternative marketing strategies and value-added systems may be necessary to provide the consumer with a more consistent product. In the ST, variability in WBS values were similar ($P > 0.05$) within the muscle, with WBS values ranging from 3.73 to 4.43 kg. These values are considered slightly tender to slightly tough (Reuter et al., 2002).

Carmack et al. (1995) evaluated beef flavor-intensity, tenderness, and juiciness among various major beef muscles. Round cuts had the most intense beef flavor ($P < 0.05$) with an exception of the ST when compared to cuts derived from the chuck or loin. This does not necessarily indicate higher flavor desirability from a consumer standpoint, as consumers have difficulty evaluating one specific palatability trait due to the halo effect. As described by Rober et al. (2005) the halo effect is the inability of panelists to completely separate tenderness, juiciness and flavor. Also, the round cuts exhibited ($P < 0.05$) lower levels of juiciness and tenderness, specifically the ST ranking the lowest ($P < 0.05$) among the eight primals for palatability traits.

Effect of enhancement, aging, and blade tenderization on palatability of beef round cuts

Alternative methods of palatability enhancement have been used within the industry to improve tenderness, juiciness, and overall flavor in various beef cuts. King et al. (2009) conducted a study that measured the effects of blade tenderization, aging time, and aging temperature on overall tenderness of beef *longissimus lumborum* and *gluteus medius* steaks. The findings from this study demonstrated that slice shear force (SSF) values were significantly reduced ($P < 0.05$) in steaks that were blade tenderized compared to those that were not, regardless of aging time or temperature. King et al. also found that aging time did not affect ($P > 0.05$) SSF values of *longissimus lumborum* and gluteus medius steaks when blade-tenderization was used (10.4, 9.9, and 9.4 kg for 12, 16, and 40 d aging, respectively). However, SSF values of non-blade tenderized steaks declined ($P < 0.05$) as aging time increased (15.1, 13.8, and 12.3 kg for 12, 26, and 40 d aging, respectively) (King et al., 2009).

Grobbel et al. (2008) evaluated packaging type and enhancement of *longissimus lumborum*, ST, and *triceps brachii* steaks. Trained sensory panelists rated enhanced steaks juicier ($P < 0.05$) than non-enhanced steaks. Furthermore, enhanced steaks had less ($P < 0.05$) perceivable connective tissue than non-enhanced steaks. Enhanced steaks had lower ($P < 0.05$) WBS values than non-enhanced steaks, indicating they were more tender than non-enhanced steaks (Grobbel et al., 2008). This supports the findings of Robbins et al. (2003) that roasts that were enhanced with water, salt and phosphate were juicier ($P < 0.05$), saltier and more tender from a trained sensory standpoint. Robbins et al. (2003) further stated that enhancement decreased ($P < 0.05$) shelf life from their control counter parts.

Gruber et al. (2006) reported a significant interaction for WBS values between individual muscle, postmortem aging period, and USDA quality grade ($P = 0.004$). Warner-Bratzler shear force values decreased for the BF (from USDA select to high Choice) and ST (from USDA select to high Choice) with increasing time of postmortem storage. However, additional aging past 21 d postmortem did not improve ($P > 0.05$) WBS values for 9 of the 16 cuts evaluated in this study, including the BF and ST (Gruber et al., 2006).

Bidner et al. (1985) found that both blade tenderizing (BT) and aging in a vacuum bag (VA) for 21 d improved (P < 0.05) tenderness by decreasing WBS values and increasing trained sensory panel ratings in strip steaks that resulted from carcasses which were electrically stimulated. Additionally BT and VA, steaks showed significantly lower amounts of connective tissue compared to their control counterparts with LS mean values of 5.7, 5.9, and 5.4, respectively (SEM 0.09) (Bidner et al., 1985). No differences were found in tenderness, connective tissue, or WBS scores among BT and VA steaks. (Bidner et al., 1985)

Robbins et al. (2003) evaluated consumer attitudes towards beef and acceptability of enhanced beef in strip steaks and round roasts with pump levels of 9.47 and 9.42%, respectively. The data collected showed that enhancement had a major effect on the sensory quality of steaks and roasts. Robbins et al. (2003) found that enhanced steaks and roasts were significantly more tender, juicy and more flavorful (P < 0.05) than controls. Beef flavor, saltiness, and overall acceptability ratings were higher for enhanced steaks and roasts when compared to controls. Warner-Bratzler shear force values for steaks and roasts were in line with the consumer findings with mean values of 1.16 and 2.47 kg, respectively, for enhanced product, while control means for steaks and roasts were at 2.26 and 3.24 kg, respectively (Robbins et al. 2002). Consumers answered survey questions regarding their consumption of enhanced products and reported that an optimal steak should be very tender and juicy and have intense beef flavor. These results suggest that enhancement increased consumer acceptability of steaks and roasts based on the sensory findings (Robbins et al., 2003).

Pietrasik and Shand (2005) studied the effects of mechanical treatments and moisture enhancement on processing and tenderness characteristics of the *semimembranosus* (SM). Pietrasik and Shand (2005) observed that brine injection significantly (P < 0.001) improved the cook yield and had the largest effect on the tenderness of SM muscles compared to other processing techniques. The SM roasts that were subjected to blade tenderization exhibited lower expressible moisture (EM) in the injected and injected/tumbled roasts in comparison to non-blade tenderized roasts. Conversely, mechanical tenderization resulted in a higher percentage of water loss in roasts that were not injected. Both pre-tumbling and blade tenderizing significantly (P < 0.05) reduced WBS values (Pietrasik and Shand., 2005). Warner-Bratzler shear force values (expressed in N = Newton, SI unit of force) were similar (P > 0.05) among blade tenderized, injected, and injected/tumbled roasts with values at 50.3, 49.4, and 44.5 N, respectively (Pietrasik and Shand., 2005). However, these treatments were more tender (P < 0.05) than non-tenderized and non-injected roasts. These results demonstrated both mechanical tenderization and enhancement are capable of improving tenderness of SM roasts (Pietrasik and Shand., 2005).

Market value of beef round cuts

Beef subprimals are clearly priced according to their expected palatability (Savell and Shackelford, 1992). Morgan et al. (1991) found that as WBS values increased price (dollars/kg) decreased. Consequently, as quality grade increases, price per kg also increases. Morgan et al. (1991) also found that round cuts at the retail level had a mean WBS of 4.31 kg, and were approximately 12% tougher than the next toughest primal cut (chuck). Specifically, top round steaks were the toughest (P < 0.05) round cut according to the WBS value (5.23 kg) obtained and had the lowest palatability ratings (Morgan et al. 1991). These data will typically reflect the prices of the round cuts at compared to the more tender cuts of the beef carcass. Savell and Shackelford (1992) found that tenderloin steaks command a \$3.83/kg over top loin steaks despite the fact that they are similar in composition. This price difference is a clear reflection of the tenderness advantage of tenderloin steaks.

Upon completion of the 1998 National Beef Tenderness Survey (NBTS), Brooks et al. (2000) implicated that cuts from the round still require more attention in processing and preparation to ensure acceptable tenderness. Tenderness seemed to improve from the 1991 NBTS; however, the round cuts were again the toughest ($P < 0.05$) as compared to the rib, loin and chuck, with WBS values ranging from 3.74 – 5.09 kg. Savell and Sheackelford, (1992) stated that there is clearly an economic loss associated with the high WBS values of round cuts.

In a study conducted by Boleman et al. (1997), top loin steaks with known shear force values were selected and divided into three groups according to tenderness. Volunteer consumers evaluated steaks and were able to purchase steaks based on their findings. Results indicated consumers were able to differentiate between the three categories of tenderness ($P < 0.05$), while also rating tender steaks higher in juiciness, juiciness satisfaction, and flavor satisfaction when compared to intermediate and tough steaks. Consumers also purchased a significantly higher number of steaks from the tender group than the intermediate or tough groups with price separations of \$1.10/kg per group. In conclusion, Boleman et al. (1997) believed consumers could detect variations in tenderness and palatability traits in steaks and were willing to pay a premium for steaks that were more tender and juicier.

SuspenTec®

The Cozzini Group (2010) states that the patented SuspenTec® process is used worldwide to process roast beef, ham, turkey breast, chicken products, steak, seafood, bacon and other various whole muscle products. The SuspenTec® process allows processors to inject lower cost protein products into higher cost whole muscle products in order to increase enhanced binding and slicing yields while decreasing cooking loss and shrink yields. This not only allows processors of fresh, cooked, refrigerated or frozen and seafood products to add value while lowering their cost of finished goods (Cozzini Group 2010)

Conclusions

Clearly, the beef industry has made leaps and bounds in terms of customer satisfaction in order to meet the demands of our consumers. There is much work left to do in order to continue to meet these needs, especially when referring to the future of the industry. It is evident that there is variation among researchers and results; however, one specific that remains the same throughout, is the need to increase general palatability traits in beef round cuts. These references support the need and success of non-intact procedures that improve overall WBS and sensory ratings, that will not only increase the overall palatability traits of low end cuts, but economic values as well. Research has not yet been published on the SuspenTec® process as an alternative non-intact procedure within the industry. The SuspenTec® process is an ideal procedure, to improve palatability traits in the challenging beef round muscles. Future work on palatability and tenderness enhancement is necessary to ensure a more pleasurable eating experience for the end consumer. Though palatability is of great importance, industry economical value must not be over looked when exploring new technologies to increase palatability. If the beef industry wants to explore other processing procedures that could hold economic value and embrace a multitude of “added value” then the SuspenTec® process is an ideal candidate.

CHAPTER III

APPLICATIONS OF THE SUSPENTEC® SYSTEM IN IMPROVING BEEF ROUND PALATIBILITY

ABSTRACT

The objective of this study was to determine the influence of the SuspenTec® system on the palatability traits of beef round cuts. In phase I, USDA Select paired beef eye of round (ER, IMPS 171C; *n* = 17) and bottom round flat subprimals (BF, IMPS 171B; *n* = 17) were selected and aged for 14 d. Subprimals were then cut into equal halves and randomly assigned to a 20% or 30% suspension of 50/50 beef trimmings incorporated in a brine solution containing salt, phosphate, and antioxidants a control group or test run group. Suspensions containing 30% trimmings improved ($P < 0.05$) the WBS of BF steaks. No significant ($P > 0.05$) differences in tenderness in WBS values between treatments was evident in ER steaks. However, there were significant ($P < 0.05$) improvements in initial juiciness, sustained juiciness, initial tenderness and overall tenderness in both ER and BF when comparing the SuspenTec® treatments to controls. These data concluded that the 20 and 30% suspension treatments showed potential in increasing palatability traits of both subprimal cuts. Though not significant ($P > 0.05$), the 30% showed tendencies of being more effective than the 20% suspension treatment in terms of improving palatability traits of round cuts. Phase II was conducted using 14 d aged ER (n = 40) and BF (n = 36) subprimals that were either processed using the 30% SuspenTec® suspension (30%), a traditional moisture enhancement (E), or blade tenderization (BT) which were compared to traditional wet aged 14 d control (CON) cuts to determine the effects on WBS, sensory traits and lipid oxidation. No differences ($P > 0.05$) in WBS of BF or TBARS in either cut were identified. However, consistent differences ($P < 0.05$) were evident among the various treatments on ER steaks, with E steaks exhibiting the most desirable WBS tenderness with BT and 30% being intermediate followed lastly by the CON steaks. From a sensory standpoint, 30% steaks showed higher levels ($P < 0.05$) of initial and sustained juiciness compared to BT and CON BF steaks. Even though no differences ($P > 0.05$) were evident in initial tenderness ratings of BF steaks, panelists rated overall tenderness of non-intact treatments as being more desirable when compared to CON counterparts. Additionally, BT reduced the amount of detectable connective tissue when compared to 30%, E and CON samples. Similarly, 30% and E increased ($P < 0.05$) the initial and sustained juiciness of ER steaks. Compared to CON ER steaks, all non-intact treatments (E, 30% and BT) improved ($P < 0.05$) the initial and overall tenderness ratings. These data support that traditionally tough round cuts can be subjected to several non-intact procedures, which ultimately improve overall palatability ratings when compared to traditionally used postmortem aging practices.

INTRODUCTION

Steak characteristics that are important to consumers include tenderness, juiciness and intense beef flavor as reported by Robbins et al. (2003). One bad eating experience can shape the way an everyday consumer purchases future products. Providing cheaper cuts of beef with desirable palatability traits can revolutionize the actions of consumers within the market. Low-end beef cuts could be portrayed as more acceptable and economical from a consumer standpoint, but only if palatability and tenderness can be enhanced. Pietrasik and Shand stated that moisture enhancement significantly ($P < 0.05$) increased cook yield and tenderness of beef *semimembranosus* muscles. This increase in plays an immense role in consumer acceptability according to Robbins et al. (2003), who found that consumers preferred enhanced strip loins over non-enhanced, and that tenderness, flavor and juiciness weighed most heavily with regard to consumer satisfaction.

The SuspenTec® technology provided by Cozzini, Inc. (Chicago, IL) offers a wide array of advances in the value added sector of the industry. This process uses traditional enhancement techniques with the concept of emulsion technologies to incorporate 50/50 beef trimmings as a suspension within the traditional brine solution. This suspension solution is, in turn, tempered to about -2°C and injected into whole muscle beef subprimals to enhance the overall palatability traits of whole muscle cuts. This process holds great value from a consumer as well as an industry standpoint, both in consumer acceptance as well as economic value.

The objectives of this experiment were; 1) determine the optimum amount of suspension that can be incorporated and injected into whole round muscles using the SuspenTec® technology in order to best improve Warner-Bratzler shear values, and optimum sensory ratings and 2) using the optimum amount, compare the tenderness and sensory attributes of the Suspentec® technology to the traditional tenderness enhancement techniques of needle tenderization, traditional enhancement, and postmortem aging.

MATERIALS AND METHODS

Phase I

Upon identifying a candidate group of USDA Select grade carcasses (*n* = 17), paired eye of round (ER, IMPS 171C), and bottom round flats (BF, IMPS 171B) were collected on the day of fabrication in the Oklahoma State University Food and Agricultural Products Center (FAPC). All eye of round muscles were trimmed according to IMPS 171C (NAMP, 2006), and bottom round flats to IMPS 171B (NAMP, 2006). Whole subprimals were then placed in a vacuum bag and packaged (MultiVac, Kansas City, KS) under 15 mbar and allowed to age for 14 d priorto the SuspenTec® process and subsequent fabrication. The SuspenTec® (Table 3.1) consisted of water, salt, phosphate, and antioxidants with levels of 94.70%, 3.00%, 2.00%, and 0.30% respectively within the brine. After mixing the salt, phosphate, and antioxidant solution, suspension was made at levels of 20% (20.11%) or 30% (30.25%) using 50/50 beef trimmings incorporated into the solution.

In order to attain the 20% suspension, 94.9 kg of brine solution was transferred to the mixing hopper where 41.17 kg of 8 mm pre ground 50/50 trim was added to achieve a consistent homogeneous mixture, and temped to -1.1°C. Once the mixture was attained the brine was pumped to the particle-reducing mill to reduce meat to micron size particles and incorporate them with the brine solution forming a suspension. Particle size was achieved after 3 min of milling and the suspension was diverted to the suspension holding hopper that feeds the injector. The final temperature of the suspension was -2.2°C. Subprimals where then halved and randomly assigned to one of three described treatments (control, 20% suspension or 30% suspension), weighed, and the suspension was pumped through a Fomaco injector (Reiser Canton, MA) at 57 psi and 22 strokes/min and ER and BF were enhanced with the suspension. The subprimals were then tumbled in a vacuum tumbler for 10 min under 25-30 psi, and re-weighed after tumbling. Final uptake was 16.9% for ER and 13.8% for BF with an initial goal of 20%. Subprimal halves were vacuum packaged and allowed to rest for 15 h before being sliced into 2.54 cm steaks. Steaks were packaged for Warner-Bratzler shear (WBS) force testing at 7, 14, and 21 d. Trained sensory panels were conducted at 7 and 14 d.

Warner-Bratzler Shear Force

Warner-Bratzler shear force (WBS) was completed using the American Meat Science Association guidelines (AMSA, 1995). Steaks were removed from the freezer (-28.8°C) and allowed to temper at 4°C for 24 h prior to cooking. Steaks were cooked on an impingement oven (XLT Impinger, Model 3240-TS, BOFI Inc., Wichita, KS) at 204.4° C to a final internal temperature of 70°C determined by an Atkins AccuTuff 340 thermocouple (Atkins Temtec, Gainesville, FL) as the steaks exited the oven. Upon completion of cooking, steaks were allowed to temper at 4°C for 24 h. Cores were taken from each steak (n = 6) parallel to muscle fiber direction. Each core was then sheared using a Warner-Bratzler head attached to an Instron Universal Testing Machine (Model 4502, Instron Corporation, Canton, MS). The crosshead speed of the Warner-Bratzler head was 200 mm/min. Peak load for each core was recorded by an IBM PS2 (Model 55

SX) using the software provided by the Instron Corp. Mean peak load (kg) was analyzed for each sample.

Trained Sensory Analysis

Sensory analysis and preparation followed AMSA guidelines (AMSA, 1995). Steaks were assigned a random number for sensory sessions. Steaks were allowed to temper in a cooler at 4°C for 24 h before cooking. Steaks were cooked to a medium degree of doneness of 70°C on an impingement oven as described for WBS. Samples were then sliced into approximately 2.54 cm X 1.27 cm X 1.27 cm cubes and served warm to panelists under red lights.

Sensory attributes were evaluated by a six member trained panel consisting of Oklahoma State University personnel. Panelists were trained for tenderness, connective tissue, and juiciness (Cross et al. 1978). Sensory sessions were performed twice daily and contained 10 samples each. Samples were evaluated using a standard ballot provided by the American Meat Science Association (AMSA, 1995). Panelists evaluated each sample in duplicate to determine initial juiciness (IJ) and sustained juiciness (SJ), initial tenderness (IT), amount of detectable connective tissue (CT), and overall tenderness (OT) as an average of IT and CT, all using an 8-point scale. For the juiciness factors the scale was 1 = extremely dry and 8 = extremely juicy. The scale for IT and OT was 1 = extremely tough and 8 = extremely tender, lastly the score for CT was 1 = abundant and 8 = none.

Throughout the course of each session panelists were randomly seated in individual booths in a temperature and light controlled room. During serving the panelists were under red filtered lights as suggested by AMSA (AMSA 1995). The samples were served randomly to each panelist. The panelists were provided distilled, deionized water and unsalted crackers to cleanse the palate.

Statistical Analysis

Data were analyzed using the MIXED model of SAS (SAS Inst. Inc., Cary, NC). The analysis of variance (ANOVA) model for WBS and sensory traits included treatment as a fixed effect and sample ID as the random effect to account for the variation from animal to animal. Interactions were observed in all models. The least square means were separated using a protected pairwise t-test when the model displayed a treatment effect ($P < 0.05$).

Phase II

Results in the initial testing determined that the 30% SuspenTec® solution was the most effective injection level that was tested. USDA Select ER (n = 40) and BF (n = 36)were obtained from National Beef Packing Co. (Dodge City, KS). These subprimals were allowed to age for 14 d post-fabrication, prior to treatment application and further fabrication.

Using the optimum results from Phase I, the treatments included the SuspenTec® 30% solution with the same brine and meat suspension as utilized in phase I, a traditional enhancement treatment that best represented the industry standard (Table 3.2) and a needle tenderized treatment. For 30%, BT, E, and CON, ER (n = 10) and BF (n = 9) were assigned to each.

The protocol for the SuspenTec® was the same as used in phase I with the following changes; subprimals were left intact and injected as a whole rather than halved. The ER and BF weights were increased by 15.37 and 24.06%, respectively, with a target of 20%. These subprimals were tumbled as previously stated in phase I and allowed to rest for 15 h before being cut into 2.54 cm steaks.

The target pump for the traditional enhancement was 10% of the original weight. The brine solution was mixed and blended 2 h prior to injection in order to acquire an adequate temperature (3.3°C) for injection. The brine solution was mixed starting with phosphate then salt and blended until dissolved, at this time the other ingredients were added until there was a homogeneous mixture achieved. Green weights were recorded prior to injection and ER and BF were pumped using a Fomaco injector (Resier, Canton, MA) with a final pump average mean of 13.6 and 10.1%. respectively. Enhanced subprimals were allowed to rest for 15 h prior to slicing into 2.54 cm steaks.

A Ross tenderizer (Ross Industries, Midland, VA) was used to needle tenderize (NT) the subprimals assigned to that treatment. The whole muscle was placed in the Ross tenderizer and one pass was made through the machine.

Upon completion of all treatments, 2.54 cm steaks were cut, vacuum packaged and allowed to age for 14 d before being frozen. Control steaks were also cut at this time and aged for 7, 14, 21, or 28 d.

Sensory analysis followed the protocol in Phase I with the following changes; panelists were trained to evaluate three specific flavor attributes (Cross et al. 1978). Panelists evaluated cooked beef flavor (BF), painty/fishy flavor (PFF) and livery/metallic flavor (LMF) intensity using a 3-point scale. The scale for BF and off flavor intensity was 1 = not detectable, 2 = slighty detectable, and 3 = strong.

Thiobarbituric Acid Reactive Substances

Lipid oxidation was evaluated by TBARS using the modified method of Buege and Aust (1978). A 10 g sample was placed in a blender (model 51BL31, Waring Products, INC., Torrington, CT) and homogenized with 30 ml of cold deionized water and placed in a disposable tube. Each tube was centrifuged for 10 min at 7°C at 3000 rpm. Two ml of supernatant was pulled from the tube and placed in a glass test tube in duplicates. Each tube had 4 ml of thiobarbituric acid/trichloroacetic acid (TBA/TCA) and 100 µl of butylated hydroxyanisol (BHA), were vortexed and then incubated in a boiling water bath for 15 min followed by a 10 min cold-water bath. Tubes were then centrifuged for 10 min at 25°C at 3000 rpm. The absorbance was read at 531 nm. Standard curves were replicated everyday of analysis using 1,1,3,3-tetra-ethoxypropane (TEP). Amount of lipid oxidation was measured in duplicate for each steak and the average absorbance reading was used for each sample. Results are reported as mg of malonaldehyde per kg of sample.

Statistical analysis for WBS and SEN in Phase II followed the protocol presented in Phase I without interaction observation. TBARS analysis of variance model included treatment as a random effect and sample ID as the random effect. LS means were separated using a protected pairwise t-test when a treatment effect was observed ($P < 0.05$).

RESULTS AND DISCUSSION

Phase I.

Effects of SuspenTec® enhancement on tenderness and palatability traits.

Results summarizing the effects of the SuspenTec® enhancement on tenderness for a WBS standpoint can be found in Table 3.3. Bottom flats that were enhanced with the 30% suspension were more tender ($P < 0.05$) than the CON or 20% suspension, implying that the 30% treatment holds the most value from a tenderness standpoint. There were no significant ($P > 0.05$) differences from an aging perspective. The ER did not show any significant ($P > 0.05$) differences from a treatment or aging standpoint. These data are contradictory to the findings of King et al (2009) who found a significant increase in tenderness as aging increased. There were no TRT X AGE interactions to report.

SuspenTec® enhancement had significant ($P < 0.05$) impacts on palatability traits of BF steaks according to the trained sensory panel ratings. As presented in Table 3.4, initial juiciness for the CON, 20%, and 30% were significantly ($P < 0.05$) increased with LS means of 5.22, 5.60 and 5.90 respectively. This agrees with the findings of Grobbel et al. (2008) that enhanced steaks are considerably juicier than non-enhanced steaks. Sustained juiciness also followed these findings in that enhanced steaks were substantially juicier as the percent suspension within the brine solution increased. Days post injection were also influential on the initial and sustained juiciness of BF steaks. At d 0 panelists found the BF steaks to be significantly ($P < 0.05$) juicier than at d 14 with means of 5.71 and 5.44, respectively. From a first impression tenderness standpoint 20%

and 30% were substantially (P < 0.05) more tender than the CON, with LS means of 5.13, 5.37, and 4.67, respectively. There were unexpectedly no differences in terms of first impression tenderness and d of aging post-injection. Contradictory to the findings of Bidner et al. (1985) and Grobbel et al. (2008), there were no differences (P > 0.05) in amount of detectable connective tissue from an aging or enhancement standpoint. Overall tenderness was significantly (P < 0.05) higher for the 30% with a LS mean of 4.96 as compared to 4.73 and 4.33 for 20% and controls, respectively.

Table 3.5 summarizes the effects of SuspenTec® on ER steaks based on a trained sensory panel. The initial findings closely reflect the results from the BF steaks. Initial juiciness of 20% and 30% SuspenTec® ER steaks were strongly related and significantly (P < 0.05) more juicy than the CON steaks representing LS means of 5.73, 5.73, and 4.57, respectively. Days aging played a factor in initial juiciness with 0 d aged steaks being considerably (P < 0.05) juicier than the 14 d aged product. As assumed, sustained juiciness followed the same trends as the initial juiciness with 20% and 30% showing significantly (P < 0.05) higher levels of sustained juiciness than their CON counterparts, with LS means of 5.21, 5.20, and 4.12, respectively. Furthermore, ER steaks at 0 d aging were consequentially (P < 0.05) juicier than those steaks aged for 14 d. First impression tenderness was influenced by enhancement, with 20% and 30% exhibiting significantly (P < 0.05) higher tenderness scores than controls, with means of 5.72, 5.81, and 5.05, respectively. As found in the sensory attributes of the BF steaks, d aging played no significant role on tenderness on ER steaks. Contradictory to the results displayed for the BF steaks, enhancement played a significant role in the connective tissue perceived in the ER steaks demonstrating LS means of 5.46, 5.40, and 4.88 for 20%, 30% and CON, respectively. Likewise overall tenderness was additionally affected by both the 20% and 30% with significant ($P < 0.05$) LS means of 5.46 and 5.40, respectively as compared to its control counterparts at 4.83. Though no differences were found among the 20 and 30% treatments in the ER steaks, these finding suggest that the 30% treatment played the most efficient role in adding value in the form of juiciness and tenderness in BF steaks. Aging product post injection posed not efficient value on palatability traits, from a trained sensory standpoint.

Phase II

Effects of SuspenTec®, traditional enhancement and blade tenderizing on tenderness and palatability traits.

Upon completion of Phase I, the 30% suspension treatment was chosen as then SuspenTec® treatment to be used in Phase II.

Unexpected WBS results (Table 3.6) were found for BF steaks with no reportable differences ($P > 0.05$) among treatments or their corresponding controls. Conversely, ER WBS values differed ($P < 0.05$) among treatments with E and BT exhibiting the lowest LS means of 3.95 and 4.59kg, respectively. The 30% SuspenTec® ER steaks, did not differ ($P > 0.05$) from its BT counterparts. Lastly, CON ER steaks were the toughest ($P < 0.05$) with a LS mean of 5.77kg.

Sensory panelists found differences ($P < 0.05$) among BF steaks in sustained and initial juiciness in BF steaks (Table 3.7). The 30% SuspenTec® and E showed the most promising results with LS means of 6.44 and 6.11, respectively for initial juiciness and 5.98 and 5.50 for sustained juiciness, respectively. This agrees with the findings of

Robbins et al. (2003) who found that tenderness, juiciness and flavor is significantly increased in enhanced steaks and roasts. There were no differences ($P > 0.05$) between E and CON groups; however, differences ($P < 0.05$) did occur between CON and BT steaks with LS means of 5.63 and 5.11, respectively for initial juiciness and 5.10 and 4.59, respectively for sustained juiciness. As with the WBS data, panelists found no differences ($P > 0.05$) in first impression tenderness. Amounts of detectable connective tissue in BF steaks, was lower ($P < 0.05$) in BT steaks when compared to the CON. Also no differences ($P > 0.05$) were found in detectable connective tissue among the 30%, and E BF steaks. Contradictory to the WBS findings, trained panelists could distinguish differences ($P < 0.05$) in overall tenderness in BF steaks. It was evident that all treatments, were more tender than CON with LS means of 5.33, 5.26, 5.57 and 4.50, respectively. Though no differences were found in WBS values, increased tenderness differences from a sensory aspect can be explained in part by the "halo effect" as described by Roeber et al. (2000). This alludes to increased amounts of juiciness within each sample altering the panelist's perception of tenderness. Cooked beef flavor, painty/fishy and livery/metallic flavors showed no treatment effects ($P > 0.05$). As expected, there were significant ($P < 0.05$) effects on saltiness (Fig 3.1) among treatment groups with 30% exhibiting the highest amount (2.78) followed by E (2.41) with lastly CON and BT representing the lowest LS means of 1.33 and 1.09, respectively.

Table 3.8 summarizes the sensory data on ER steaks in terms of tenderness and juiciness. As expected, E and 30% steaks exhibited the most desirable values in terms of initial and sustained juiciness. Though E and 30% did not differ from each other, they were significantly ($P < 0.05$) juicier than BT and CON ER steaks. Tenderness for ER steaks more closely reflected the results from the WBS data than that of the BF steaks. Sensory panelists found distinct differences (*P* < 0.05) among treatments for first impression and overall tenderness. The E steaks held the highest values for initial and overall tenderness with LS means of 6.00 and 5.90, respectively. Also the 30% SuspenTec® was increased significantly (P < 0.05) when compared to the control counterparts in first impression and overall tenderness. The lowest treatments in terms of sensory tenderness were BT and CON for initial and overall tenderness with LS means of 4.95, 4.98 and 4.67, 4.60, respectively. Panelists could not detect any differences (*P* < 0.05) in connective tissue among treatments.

Off flavors such as cooked beef, painty/fishy and livery/metallic in ER steaks were not significantly (*P* > 0.05) detectable to panelists (Fig 3.2). The ER steaks followed the same trend as the BF steaks in terms of saltiness with the E and 30% steaks representing the highest levels of salt reflecting LS means of 2.41 and 2.16, respectively. The CON and BT steaks, though not different from each other were significantly (*P* < 0.05) lower than their 30% and E counterparts with LS mean values of 1.13 and 1.08, respectively (Fig 3.2).

Fig 3.3 shows no reportable differences (*P* > 0.05) in TBAR values. These findings agree with those of Campo et al. (2006) that the aforementioned off flavors are strongly associated with TBARS values.

Conclusion

Though no differences were found in BF steaks form a WBS standpoint, there were positive palatability increases associated with the three major treatments represented in this study. Furthermore, the only off flavor associated with these various treatments to be detected was saltiness. The ER steaks showed significant increases in tenderness from a WBS standpoint with the same exhibited palatability increases as the BF steaks form a trained sensory perspective.

The SuspenTec® technology showed very promising results from a trained sensory panel perspective. Though not surpassing traditional enhancement techniques the SuspenTec® did show potential for great improvement in beef round muscles. Further research needs to be conducted on suspension composition and application of the process in the industry.

Table 3.1. SuspenTec® brine solution percentages for Phase I based on 120% injection of original weight

Ingredient	**Percent within brine**	**Pump Percent**	**Percent in end product**
Water	94.70	19.00	---
Salt	3.00	0.60	0.50
Phosphate- Brifisol 85 instant	2.00	0.25	0.21
Antioxidant- VIVOX 4	0.30	0.06	0.05

Table 3.2. Traditional brine solution percentages for Phase II based on 110% injection of initial weight

Ingredients	Percent in Brine	Percent in final product
Water	73.75	---
Purasal P Plus (78%)	16.20	1.50
Phosphate- Brifisol 750	4.21	0.39
Salt	3.88	0.36
Proliant B1301 Beef Stock	1.40	0.13
Antioxidant- VIVOX 4	0.54	0.05

Table 3.3. Effect of SuspenTec® enhancement and postmortem aging (d 0, 7, 14, 21) on Warner- Bratzler shear force (kg) of bottom round flat (n = 204) and eye of round steaks (n = 204)

Item	Bottom Round Flat	Eye of Round
Treatment		
Control	6.60[b]	5.67
20% Injection	6.29[b]	5.44
30% Injection	5.64[a]	5.55
SEM	0.22	0.17
Days Postinjection		
0	5.93	5.87
7	6.36	5.45
14	6.47	5.41
21	5.96	5.48
SEM	0.26	0.20

[a.b] Means in the same column, within a main effect, with superscripts that do not have a common letter differ ($P < 0.05$)

Table 3.4. Effect of SuspenTec® enhancement on trained sensory panel ratings of bottom round flat steaks (n = 102) at 0 and 14 d post-injection

Item	Initial Juiciness[a]	Sustained Juiciness[a]	Tenderness (first Impression)[b]	Connective Tissue[c]	Tenderness (Overall Impression)[b]
Treatment					
Control	5.22^{f}	4.77^{f}	4.67^{e}	4.17	4.33^{e}
20% Injection	5.60^{e}	5.10^{e}	5.13^{d}	4.44	4.73^{e}
30% Injection	5.90^{d}	5.43^{d}	5.37^{d}	4.56	4.96^{d}
SEM	0.14	0.09	0.13	0.15	0.14
Day Postinjection					
0	5.71^{g}	5.27^{g}	5.04	4.34	4.67
14	5.44^{h}	4.92^{h}	5.07	4.43	4.67
SEM	0.08	0.08	0.13	0.12	0.12

[a]8 = extremely juicy, 1= extremely dry

[b]8 = extremely tender, 1= extremely tough

[c]8 = none, 1= abundant

[d,e,f,g,h]Means in the same column, within a main effect, with superscripts that do not have a common letter differ ($P < 0.05$)

Table 3.5. Effect of SuspenTec® enhancement on trained sensory panel ratings of eye of round steaks (n = 102) at 0 and 14 days post-injection

Item	Initial Juiciness[a]	Sustained Juiciness[a]	Tenderness (first Impression)[b]	Connective Tissue[c]	Tenderness (Overall Impression)[b]
Treatment					
Control	4.57[e]	4.12[e]	5.05[e]	4.88[e]	4.83[e]
20% Injection	5.73[**d**]	5.21[d]	5.72[d]	5.46[d]	5.49[d]
30% Injection	5.70[d]	5.20[d]	5.81[d]	5.40[d]	5.53[d]
SEM	0.11	0.11	0.10	0.10	0.10
Day Postinjection					
0	5.53[f]	5.06[f]	5.52	5.26	5.24
14	5.14[g]	4.62[g]	5.54	5.23	5.32
SEM	0.09	0.09	0.08	0.08	0.08

[a]8 = extremely juicy, 1= extremely dry

[b]8 = extremely tender, 1= extremely tough

[c]8 = none, 1= abundant

[d,e,f,g]Means in the same column, within a main effect, with superscripts that do not have a common letter differ ($P < 0.05$)

Table 3.6. Effect of SuspenTec®, traditional enhancement and blade tenderizing on Warner- Bratzler shear force (kg) of bottom round flat (n = 36) and eye of round steaks (n = 40)

Item	Bottom Round Flat	Eye of Round
Control	7.16	5.77[c]
30% SuspenTec®	7.82	4.83[b]
Traditional Enhancement	6.50	3.95[a]
Blade Tenderized	5.92	4.59[ab]
SEM	0.65	0.33

[a,b,c] Means in the same column, within a main effect with superscripts that do not have a common letter differ ($P < 0.05$)

Table 3.7. Effect of SuspenTec®, traditional enhancement and blade tenderizing on trained sensory panel ratings of bottom flat steaks (n = 36) at 14 d post-injection

Item	Initial Juiciness[a]	Sustained Juiciness[a]	Tenderness (First Impression)[b]	Connective Tissue[c]	Tenderness (Overall Impression)[b]
Treatment					
Control	5.63[e]	5.10[e]	4.73	4.63[e]	4.50[e]
30% SuspenTec®	6.44[d]	5.98[d]	5.59	5.31[de]	5.33[d]
Traditional Enhancement	6.11[de]	5.50[de]	5.59	5.17[de]	5.26[d]
Blade Tenderized	5.11[f]	4.59[f]	5.70	5.78[d]	5.57[d]
SEM	0.21	0.20	0.24	0.26	0.23

[a]8 = extremely juicy, 1= extremely dry

[b]8 = extremely tender, 1= extremely tough

[c]8 = none, 1= abundant

[d,e,f] Means in the same column, within a main effect with superscripts that do not have a common letter differ ($P < 0.05$)

Table 3.8. Effect of SuspenTec®, traditional enhancement and blade tenderizing on trained sensory panel ratings of eye of round steaks (n = 40) at 14 d post-injection

Item	Initial Juiciness[a]	Sustained Juiciness[a]	Tenderness (First Impression)[b]	Connective Tissue[c]	Tenderness (Overall Impression)[b]
Treatment					
Control	3.93[e]	3.40[e]	4.67[f]	5.43	4.60[f]
30% SuspenTec®	5.30[d]	4.77[d]	5.45[e]	5.81	5.45[e]
Traditional Enhancement	5.67[d]	5.17[d]	6.00[d]	6.05	5.90[d]
Blade Tenderized	3.92[e]	3.36[e]	4.95[f]	5.57	4.98[f]
SEM	0.18	0.18	0.16	0.25	0.16

[a]8 = extremely juicy, 1= extremely dry

[b]8 = extremely tender, 1= extremely tough

[c]8 = none, 1= abundant

[d,e,f]Means in the same column, within a main effect with superscripts that do not have a common letter differ ($P < 0.05$)

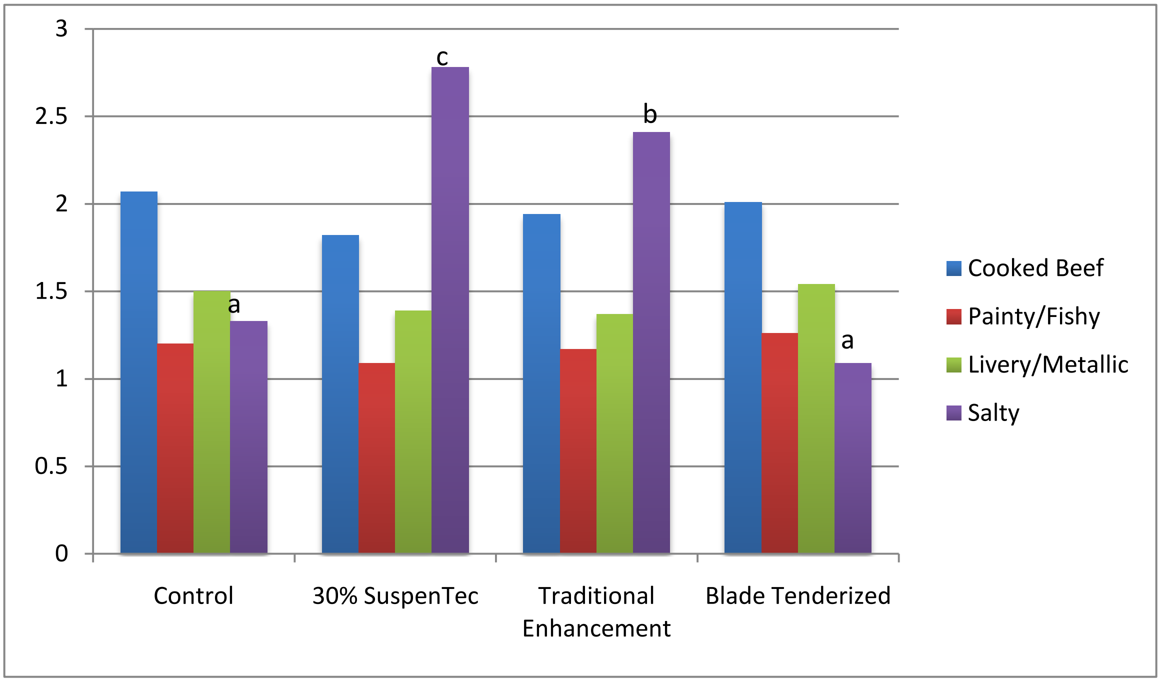

Figure 3.1. Cooked beef, painty/fishy, livery/metallic and salty (pooled SEM of 0.07, 0.07, 0.07 and 0.09 respectively) associated with SuspenTec®, traditional enhancement, blade tenderizing and control in bottom round flat steaks (*n* = 36) at 14 d post-injection. [a,b,c] Means in the same flavor profile, within a main effect with superscripts that do not have a common letter differ ($P < 0.05$)

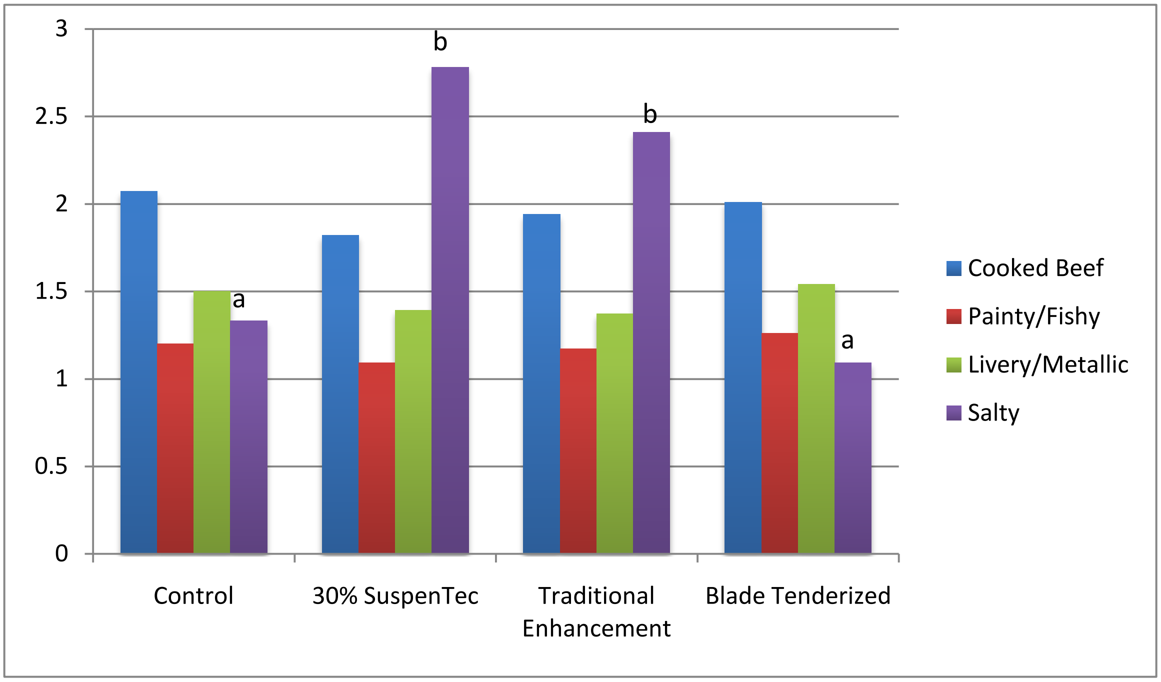

Figure 3.2. Cooked beef, painty/fishy, livery/metallic and salty (pooled SEM of 0.07, 0.01, 0.07 and 0.10 respectively) associated with SuspenTec®, traditional enhancement, blade tenderizing and control in eye of round steaks (n = 40) at 14 d post-injection. [a,b] Means in the same flavor profile, within a main effect with superscripts that do not have a common letter differ ($P < 0.05$)

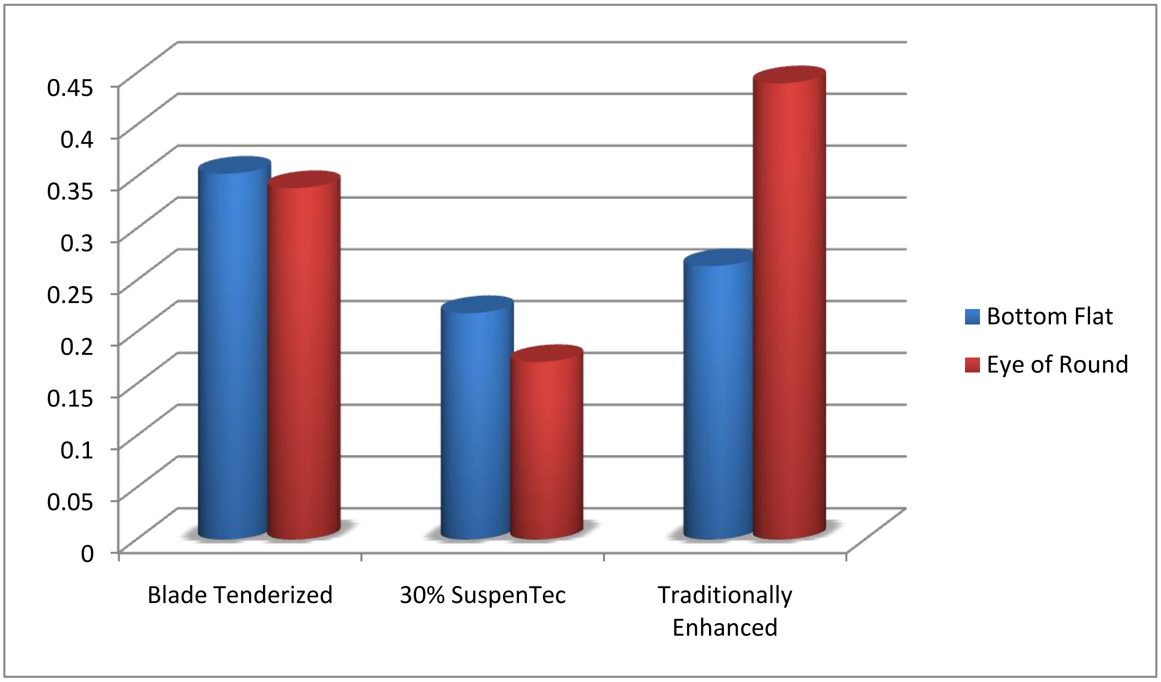

Figure 3.3. TBARS values associated with SuspenTec®, traditional enhancement and blade tenderizing in eye of round (*n* = 40, pooled SEM 0.10) and bottom flat steaks (*n* = 36, pooled SEM 0.05) at 14 d post-injection.

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VITA

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Master of Science

Thesis: APPLICATIONS OF THE SUSPENTEC® SYSTEM IN IMPROVING BEEF ROUND PALATIBILITY

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Institution: Oklahoma State University Location: Stillwater, Oklahoma

Title of Study: APPLICATIONS OF THE SUSPENTEC® SYSTEM IN IMPROVING BEEF ROUND PALATIBILITY

Pages in Study: 43 Candidate for the Degree of Master of Science

Major Field: Animal Science

Scope and Method of Study: The objective was to determine the influence of the SuspenTec® system on the palatability traits of beef round cuts. In phase I, USDA Select paired beef eye of round (ER), and bottom round flat subprimals (BF), were selected, aged for 14 d and cut into equal halves and randomly assigned to a 20% or 30% suspension of 50/50 beef trimmings incorporated in a brine solution containing salts, phosphates, and antioxidants or a control group. Each treatment was injected to a target weight of 120%. Subprimal halves were fabricated into 2.54 cm steaks for Warner-Bratzler shear force (WBS) and sensory analysis (SEN). Phase II was conducted using 14 d aged ER (n=35) and BF (n=32) subprimals that were either processed using the 30% SuspenTec® suspension (30%), a traditional enhanced (E), or blade tenderized (BT) which were compared to traditional wet aged 14 d controls (CON) to determine their effects on WBS, SEN and lipid oxidation using thiobarbituric acid reactive substances (TBARS).

Findings and Conclusions: In Phase I suspensions containing 30% trimmings improved ($P < 0.05$) the WBS of BF steaks while their 20% counterparts showed no differences. No differences ($P > 0.05$) in tenderness in WBS values between treatments was evident in ER steaks; however, there were significant ($P < 0.05$) improvements in initial juiciness, sustained juiciness, initial tenderness and overall tenderness in both ER and BF when comparing the SuspenTec® treatments to controls. Phase II showed no differences ($P > 0.05$) in WBS of BF or TBARS in either cut, however, differences ($P < 0.05$) were evident among the various treatments on ER steaks, with E steaks exhibiting the most desirable WBS tenderness with BT and 30% being intermediate followed lastly by the CON steaks. Sensory values showed, 30% steaks with higher levels ($P < 0.05$) of initial and sustained juiciness compared to CON and BT BF steaks. Panelists rated overall tenderness of non-intact treatments as being more desirable when compared to CON counterparts. Similarly, 30% and E affected ($P < 0.05$) the initial and sustained juiciness of ER steaks. Compared to CON ER steaks, all non-intact treatments improved ($P < 0.05$) the initial and overall tenderness ratings.

ADVISER'S APPROVAL: Dr. Brad Morgan