

Effects of Antioxidant Application and Retail Display on Sensory, Shelf Life, and Oxidative Stability of Beef Striploin Steaks¹

Lee M. Batot¹
Jennie A. Canon¹
Kaci L. Foote¹
Mark F. Miller²
Robert P. Cope¹
Loree A. Branham¹
Kirk W. Braden^{*,1}

¹*Angelo State University, San Angelo, TX 76909*

²*Texas Tech University, Lubbock, TX 79409*

ABSTRACT

Beef strip-loin steaks were treated with GRAS (generally recognized as safe) approved antioxidant formulations: citric acid (CIT) 0.3%, synthetic butylated hydroxyanisole/butylated hydroxytoluene (SYN) 0.08% and a control (CON) of distilled water. Strip-loins (IMPS # 180) (n = 32) at postmortem day 14, 21, and 28 were removed from vacuum packages and fabricated into 2.54-cm steaks. Steaks (n = 63) were randomly assigned to treatment groups (n = 21 samples/treatment). After treatment steaks were over-wrapped, and placed in simulated retail display for five display days (DD). Sensory attributes were not affected by treatment ($P > 0.05$). SYN treatment maintained strip-loin color ($P < 0.05$) while CON and CIT exhibited additional discoloration in DD 4 and 5 compared to SYN across ageing periods. CON and CIT contained additional browning in DD 3-5 ($P < 0.05$) than SYN. SYN exhibited greater a^* values through DD periods ($P < 0.05$) when compared to CON or CIT. SYN exhibited greater oxymyoglobin level ($P = 0.03$) and reduced metmyoglobin levels ($P < 0.05$) throughout DD and PM ageing. CON and CIT exhibited increased oxidation on DD 1, 3, and 5 compared to SYN ($P < 0.05$). SYN application prolonged retail display shelf life by maintaining color and reducing lipid oxidation without negatively affecting sensory attributes.

KEY WORDS: beef, striploin, antioxidant, shelf life, sensory

* Corresponding author: kbraden4@angelo.edu

INTRODUCTION

Overall, the meat industry's role is to provide quality products to satisfy needs of the consumer in the world (Resurreccion 2003). Depending on the region, over one-fourth to one-third of the worldwide production of meat is lost every year because of deteriorating product quality (Oussalah et al. 2004). It has been estimated that average value deterioration is 3.7% for the entire meat department and 5.4% for fresh meat (Williams et al. 1992). Williams et al. (1992) also stated that the U.S. industry stands to gain \$175 million to \$1 billion annually by increasing case life by one to two days. A percentage of this magnitude gives prime evidence why more research and development is needed for the preservation and maintenance of fresh retail meat products. Changing consumer demands in the U.S. have influenced the market for all types of meat. Due to these overall changes in demands, the meat products that are produced for sale and consumption must be of high standard quality and transportable to vast marketplaces located long distances away from production facilities. Meat is a highly perishable food; both oxidative and microbial processes are involved in meat spoilage (Camo et al. 2008). Flavor, color and shelf life all are related to the oxidative state of meat. A major setback cited by supermarket meat managers is discoloration which cause beef retail products to be discounted or discarded depending on expiration date or shelf life of the product (Steiner et al. 2001). When muscle cuts are discolored on or before the sell by date, retail cuts must be marked down in price, faced, or repackaged (Smith et al. 1993).

When products are re-handled or the form of original product is changed, there is usually a loss of quality and value, along with the added chance of microbial contamination. The average consumer bases the purchase of a product predominantly on visual appearance, of which color is the number one factor (Marth 1998). A bright cherry red color characterizes a freshly cut steak and is the desired visual characteristic of choice. Meat markets, which still use over wrap packaging of products, have an increased problem with oxidation and bacterial loads when compared to products packaged in a modified oxygen environment (Jeremiah and Gibson 1997). Oxidation is a chemical change of fat and muscle pigments that leads to rancidity, color changes and flavor deterioration. Over wrap is the most economically feasible method for retail display, but there is limited control of oxygen levels and other environmental factors associated with product deterioration. Lipid and protein oxidation is a critical point for red meat packaged under aerobic conditions, since it occurs at the same rate as discoloration and faster than microbial growth (Camo et al. 2008). Past research has focused on the use of antioxidants in ground and processed meat products for oxidative stability and overall shelf life (Greene et al. 1971). Limited research has been conducted on the basis that defines effects of antioxidant application on color, oxidative stability, and shelf life of whole muscle beef steaks over extended time in a retail environment. Correspondingly, the objectives of the current study are to evaluate: 1) effects of specified antioxidants on sensory properties of beef strip-loin steaks, and 2) effects of specified antioxidants on surface color and oxidative stability of fresh beef striploin steaks.

MATERIALS AND METHODS

Treatments. Experimental treatments consist of two antioxidant formulations and a control to determine the overall effect of antioxidant application. Control group (CON) was applied with distilled deionized water. Antioxidant treatments consisted of 0.3%

citric acid solution (CIT; 1 L distilled deionized water + 3 g of food grade citric acid) and 0.08% solution of butylated hydroxyanisole and butylated hydroxytoluene (SYN; 1 L distilled deionized water + 0.4 g Butylated hydroxyanisole and 0.4 g butylated hydroxytoluene) (Table 1; Integra Chemicals, Kent, WA). Solution preparation consisted of heating distilled deionized water to 37 °C, and then adding chemical component into water under high shear. These formulations were calculated once the level of uptake was determined to be 4 g solution / striploin steak sample. All antioxidant treatments were formulated in accordance to guidelines set forth in CFR 184.0(b)(1).

Table 1. Experimental treatment formulations applied to striploin steaks.

Treatment ^a	Formulation
Control (CON)	Distilled deionized water
Citric acid (CIT)	^b 0.3% citric acid + distilled deionized water
Butylated hydroxyanisole/ Butylated hydroxytoluene (SYN)	^c 0.08% Solution (BHA/ BHT) + distilled water

^a All treatments resulted in a uptake equaling 4.0 g of solution formulated based on accordance guidelines set forth in CFR 184.0(b)(1).

^b Citric acid treatment (0.3% solution) 3 g citric acid/ 1 L distilled deionized water.

^c Butylated hydroxyanisole/ Butylated hydroxytoluene treatment (0.08% solution) 0.4 g BHA 0.4 g BHT/ 1 L distilled deionized water.

An automated belt line was utilized to transport each sample through an atomization cabinet where application of treatment solution (CON, CIT, and SYN) from a top mounted surface nozzle was applied while a constant level of pressure (275,790 pa) was maintained. A constant speed setting was used on the belt line to increase the rate of accuracy of treatment uptake of 4 g per steak. Sample weight was taken before and after application of treatment to ensure application of 4 g of solution per steak.

Sample Selection. Wholesale beef striploins (n = 32; IMPS #180, USDA, 1996) were obtained from a commercial beef plant in Plainview, TX, vacuum packaged, and transported to the Angelo State University Food Safety and Product Development Laboratory under refrigerated storage. Temperature recorders (DataWatch, Global Sensors, Belmont, NC) were utilized to ensure striploin temperatures remained below 4 °C during transport. Wholesale striploins were selected within a specified window of USDA quality and yield grading to minimize inherent variation. All selection criteria were evaluated by trained personnel according to USDA quality and yield grade guidelines (USDA 1989).

Sample Preparation. Striploins were wet aged in vacuum package bags for 14, 21, and 28 days postmortem to simulate the approximate time beef remains in storage and transit prior to consumer availability. Sixteen wholesale strip-loins were utilized per trial. On days 14, 21, and 28 postmortem strip-loins were fabricated into four 2.54 cm thick steaks cut from the anterior end of each strip-loin. One steak of the total was randomly discarded to achieve equal representation within each of three treatments. Steaks (n = 63) were then randomly assigned to one of the three treatment groups (CON, CIT, or SYN) to achieve n = 21 samples/treatment. Strip-loin steaks within each treatment were then trimmed down to 0.06 cm external fat thickness to maintain sample consistency. Within each treatment group (n = 21) steaks were randomly assigned to one of three display day

(DD) ageing treatments (DD 1, DD 3, and DD 5) to achieve seven steaks per DD ageing treatment. Within each DD ageing treatment, four steaks were assigned to lipid oxidative stability analysis. Three steaks were assigned to sensory analysis within each DD ageing treatment combination. Steaks for lipid oxidative stability and sensory evaluation analysis were removed from simulated retail display according to specified DD ageing treatment, vacuum packaged and stored at -0 °C for subsequent analysis.

Simulated Retail Display. Immediately post treatment application steaks were placed on a standard retail grade Styrofoam tray, coded with sample identification and overwrapped with polyvinyl chloride film (PVC) to mimic retail presentation. Within one hour of treatment application, all steaks were placed in simulated retail display. Steaks were randomly placed in a Tyler retail display case (Model NM8, Tyler Refrigeration Corporation, Niles, MI) to mimic retail display conditions. Case temperature was maintained at 4 °C and exposed to optimum retail display lighting (Promolux Safe Spectrum T8 Platinum, Shawnigan Lake, BC, Canada) with illumination intensity maintained near 1900 lux. Simulated retail display was adapted from a previously published procedure (Braden et al. 2007).

Sensory Evaluation. Prior to the start of evaluation, a sensory training session was conducted in reference to procedures of Cross et al. (1978) so trainees would understand testing procedures and evaluation of sample meat products. Steaks were removed from frozen storage and placed under refrigeration (4 °C) 24 hours prior to sensory evaluation. Steaks were cooked on a George Forman electric clam shell style grill (Applia Consumer Products, Bedford Heights, OH) to an internal temperature of approximately 71 °C to achieve a medium degree of doneness according to procedures outlined by Kerth et al. (2003). Steaks were then cut into 1-cm³ cubes and stored in warming pans until the entire panel was prepared. All samples were served to sensory panel warm within 15 minutes of cook time. At least six trained individuals were utilized for sensory evaluation during each panel. Apple juice, unsalted crackers, and water were provided to each panelist to properly cleanse the pallet between each sample. Steaks were analyzed for initial and sustained juiciness, initial and sustained tenderness, flavor intensity, off flavor, and overall acceptability according to ballot scaling procedures of Cross et al. (1978).

Visual Color Evaluation. Subjective color training was conducted prior to research to ensure no color vision deficiencies were present in the panel. During a five-day display period, steaks were evaluated daily by a trained panel, consisting of at least six members. The daily color evaluation was conducted within a one hour window for daily evaluation throughout each postmortem period for beef color, color uniformity, surface discoloration, and lean browning according to AMSA (1991) color panel evaluation guidelines.

Objective Color Evaluation. Commission Internationale de l'Eclairage (CIE) L* (muscle lightness), a* (muscle redness), b* (muscle yellowness), and reflectance spectra values were determined daily through the overwrap for display day from two random readings on each steak with a Hunter Miniscan XE Plus (Hunter Associates Laboratory, Inc., Reston, VA) using illuminate D65 at 10° and a 3.5 cm aperture. Spectral reflectance values were determined and recorded every 10 nm over a range of 400-700 nm. Muscle chroma (color intensity/saturation), hue, angle (wavelength of light radiation red, yellow,

green, blue, and purple), myoglobin (fresh muscle pigment), oxymyoglobin (oxygenated muscle pigment), and metmyoglobin (brown oxidized muscle pigment) values were obtained utilizing equations as described by Hunt (1980) and Clydesdale (1991). Visual and instrumental color analysis protocols were utilized similar to those as presented by Braden et al. (2007).

Oxidative Stability Assessment. Lipid oxidative stability was determined utilizing a thiobarbituric acid (TBA) reactive substance assay as detailed by Buege and Aust (1978). Lipid oxidative stability samples from display days 1, 3, and 5 were removed from frozen storage and a 10 g sample was homogenized with 30 mL of distilled water. Approximately 4 mL of homogenate was combined with 8 mL of trichloroacetic/thiobarbituric acid reagent and 100 μ L of 10% butylatedhydroxyanisole. Samples were then incubated in a 99 °C water bath for 15 minutes, allowed to cool in cold water (4 °C) for 10 minutes and spun at 2000 x g for 10 minutes. The absorbance of the supernatant was then read against a blank containing like reagents at 531 nm. Malonaldehyde standard, utilizing 1,1,3,3-tetraethoxypropane and thiobarbituric acid, was used and thiobarbituric acid substances were reported as mg/10g of meat.

Statistical Analysis. Sensory and TBA data was analyzed as a completely randomized design using the general linear models procedures of SAS (SAS Inst. Inc., Cary, NC). Sensory and TBA data was included in the model with treatment as a fixed effect. DD 1, 3, and 5 visual and instrumental color data was analyzed for a completely randomized design, with a split plot repeated measures arrangement using the mixed models procedures as implemented in PROC MIXED (Littell et al. 1996; SAS Inst. Inc., Cary, NC). Visual color, lean uniformity, lean discoloration, lean browning, L*, a*, b*, Chroma, hue, myoglobin, oxymyoglobin, and metmyoglobin values were included in the model with treatment and display day and all two way interactions as fixed effects. Display day was analyzed as a repeated measure with steak as the subject of the repeated statement and based on AICC criteria an optimum covariance structure was selected (Littell et al. 1996). Steak served as experimental unit and significant ($P \leq 0.05$) treatment effect means were separated using Fisher's protected LSD.

RESULTS AND DISCUSSION

Color Measurements. All subjective measurements taken by trained panelists deteriorated over time, as steaks reached the extent of their display day periods throughout each postmortem aging period. Color score was evaluated for treatment x display day x postmortem aging ($P < 0.001$; Figure 1). When controlling for display day, there was no treatment x postmortem aging ($P = 0.51$) effect. A desired bright cherry red color was maintained by SYN treatment for a longer period of time when compared to CON and CIT, especially during display days 3, 4, and 5 of postmortem aging period 28 (Figure 2). For lean discoloration scores there was treatment main effect ($P = 0.01$) and for treatment x display day x postmortem aging ($P < 0.001$; Figure 3); but not for treatment x display day ($P = 0.11$) or treatment x postmortem aging ($P = 0.37$). SYN treatment exhibited less discoloration in later display day periods of postmortem aging periods 21 and 28 when evaluated by panelist. Lean browning was effected by treatment x postmortem aging x display day ($P < 0.001$). A lower level of browning was observed by panelist for steaks from SYN treatment throughout all three postmortem periods.

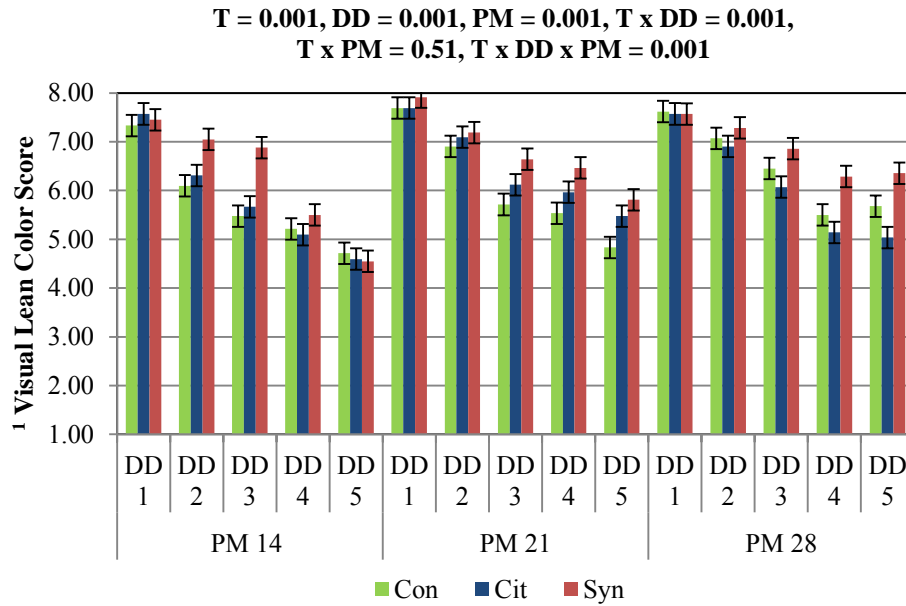


Figure 1. Least square means \pm SEM for visual lean color of striploins by retail display day within postmortem aging days. Treatments consisted of control (CON), citric acid (CIT), and BHA/BHT (SYN); T = treatment, DD = days of simulated retail display, and PM = days of postmortem aging ¹Lean color uniformity (1 = extremely dark red; 8 = extremely bright cherry-red).

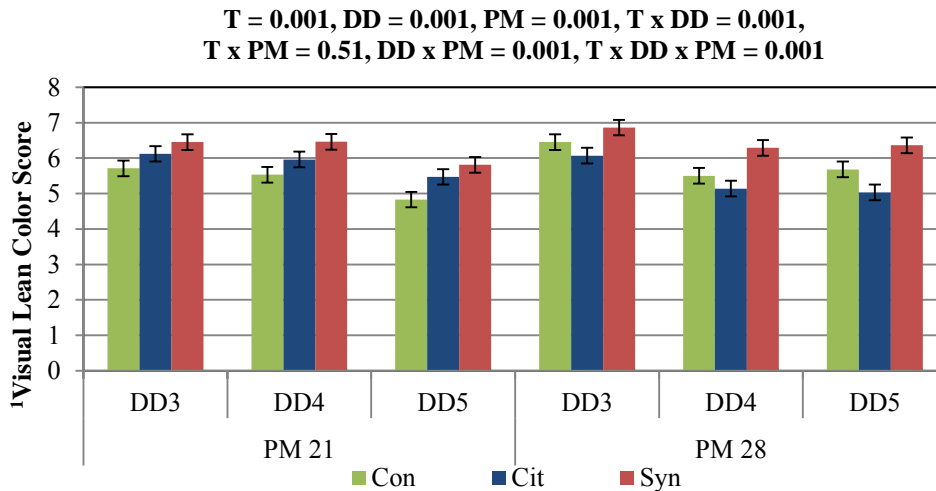


Figure 2. Least square means \pm SEM for visual lean color of striploins by retail display day (3-5) within postmortem aging days (21 and 28). Treatments consisted of control (CON), citric acid (CIT), and BHA/BHT (SYN); T = treatment, DD = days of simulated retail display, and PM = days of postmortem aging ¹Lean color uniformity (1 = extremely dark red; 8 = extremely bright cherry-red).

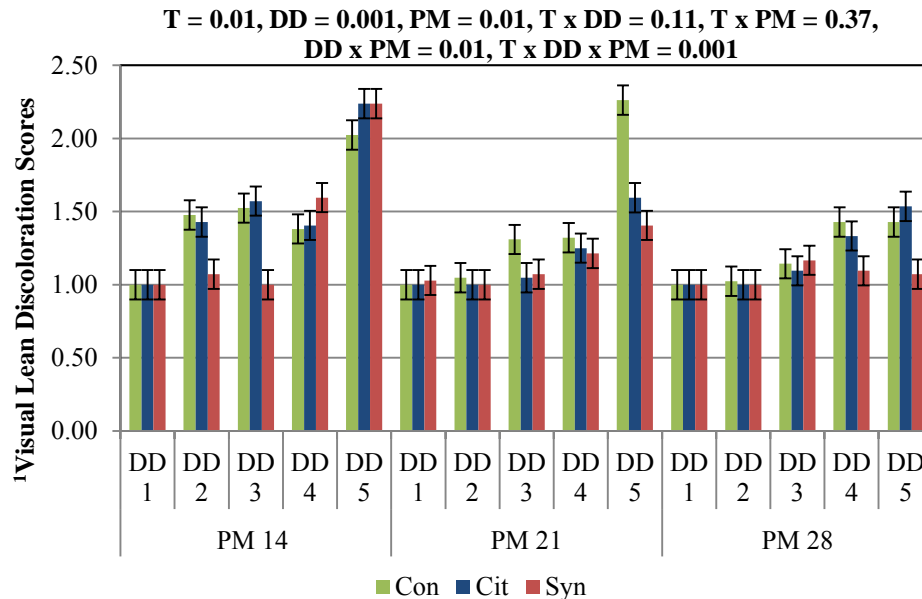


Figure 3. Least square means \pm SEM for visual lean discoloration of striploins by retail display within postmortem aging days. Treatments consisted of control (CON), citric acid (CIT), and BHA/BHT (SYN); T = treatment, DD = days of simulated retail display, and PM = days of postmortem aging; ¹Lean discoloration (1 = 0%; 7 = 100%).

With increased postmortem and retail display day aging, all objective color attributes declined ($P < 0.05$). As these objective color measurements decreased there were varied rates of decline according to variable, treatments, treatments x display day, treatment x postmortem aging, and treatment x display day x postmortem aging combinations.

CIE L* values ($P < 0.001$), were slightly lower for SYN treatments when compared to CON and CIT treatments. No two way interaction for CIE L* values were seen for treatment x display day ($P = 0.74$) or treatment x postmortem aging ($P = 0.13$). There was an interaction for treatment effect on CIE a* values for treatment x postmortem aging ($P = 0.004$; Figure 4) but not for treatment x display day ($P = 0.52$). When comparing a* values between the three treatments during each postmortem period the SYN treatment had higher overall values, being more red when compared to the CON and CIT application. CIE b* values were similar to a* findings as interactions of treatment x postmortem aging ($P < 0.001$; Figure 5) along with treatment x display day ($P < 0.001$) values tended to be higher (more yellow) in steaks receiving SYN treatment. There were no interactions of display day x treatment ($P = 0.76$) or treatment x display day x postmortem aging ($P = 0.87$). Chroma values did show a positive treatment x postmortem aging affect ($P < 0.001$; Figure 6) where SYN treatment maintained higher levels of color saturation when compared to CON and CIT in all ageing periods. There were no interactions of treatment x display day ($P = 0.61$) or treatment x display day x postmortem aging ($P = 0.54$) when evaluating chroma. For Hue, there was only a positive treatment effect ($P < 0.001$) where SYN had lower hue values when compared to CON and CIT treatments. When evaluating myoglobin levels, there were interaction effects

due to treatment x display day x postmortem aging ($P < 0.001$; Figure 7). Myoglobin (fresh muscle pigment) levels were maintained for longer periods of time by SYN treatment in the later of display days 3, 4, and 5. When samples were evaluated for oxymyoglobin content there was an effect due to treatment x postmortem aging x display day ($P = 0.011$; Figure 8). The oxymyoglobin levels were maintained higher for SYN treated steaks when comparing display days 4 and 5 throughout all three postmortem periods. Metmyoglobin levels were substantially dependent upon treatment effect ($P < 0.001$) were SYN (36.38) was lower in value for oxidized myoglobin pigment when compared to CON or CIT (38.52 and 38.28, respectively). No two-way or three-way interactions for treatment had an effect ($P > 0.05$).

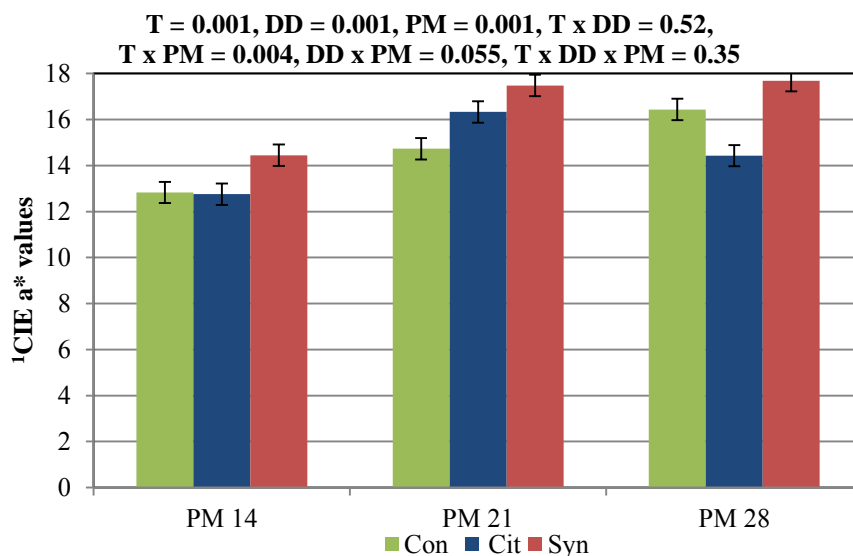


Figure 4. Least square means \pm SEM for CIE a* instrumental values of striploin steaks by postmortem aging period. Treatments consisted of control (CON), citric acid (CIT), and BHA/BHT (SYN); T = treatment, DD = days of simulated retail display, and PM = days of postmortem aging; ¹CIE a* value (positive = red, 0 = neutral, negative = green).

According to Mancini and Hunt (2005), meat color is the greatest quality factor that influences a meat purchasing decision made by consumers since it's an indicator of freshness and wholesomeness. As a result, nearly 15% of retail beef is discounted in price due to surface discoloration, which corresponds to annual revenue losses of \$1 billion (Smith et al. 1993). Visual color analysis provides evidence that is more comparable to consumer's perception of color than instrumental color analysis. The use of instrumental color analysis does provide scientific measurements that are widely accepted and comparable throughout many different criteria. Economic improvements associated with products that improve color life potential and stability has been sought after for many years.

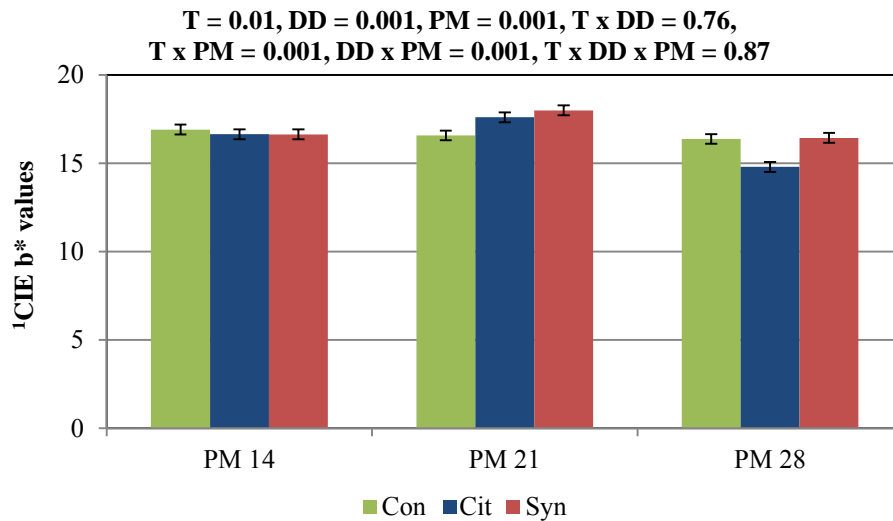


Figure 5. Least square means \pm SEM for CIE b* instrumental values of striploin steaks by postmortem aging days. Treatments consisted of control (CON), citric acid (CIT), and BHA/BHT (SYN); T = treatment, DD = days of simulated retail display, and PM = days of postmortem aging; ¹CIE b* Value (positive = yellow, 0 = neutral, negative = blue).

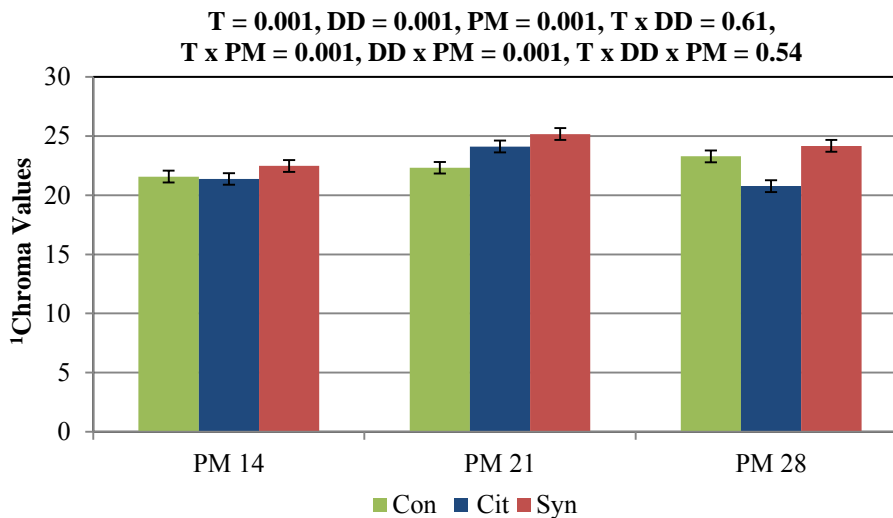


Figure 6. Least square means \pm SEM for lean chroma instrumental values of striploin steaks by postmortem aging days. Treatments consisted of control (CON), citric acid (CIT), and BHA/BHT (SYN); T = treatment, DD = days of simulated retail display, and PM = days of postmortem aging; ¹Lean Chroma Value (numerically increasing color saturation).

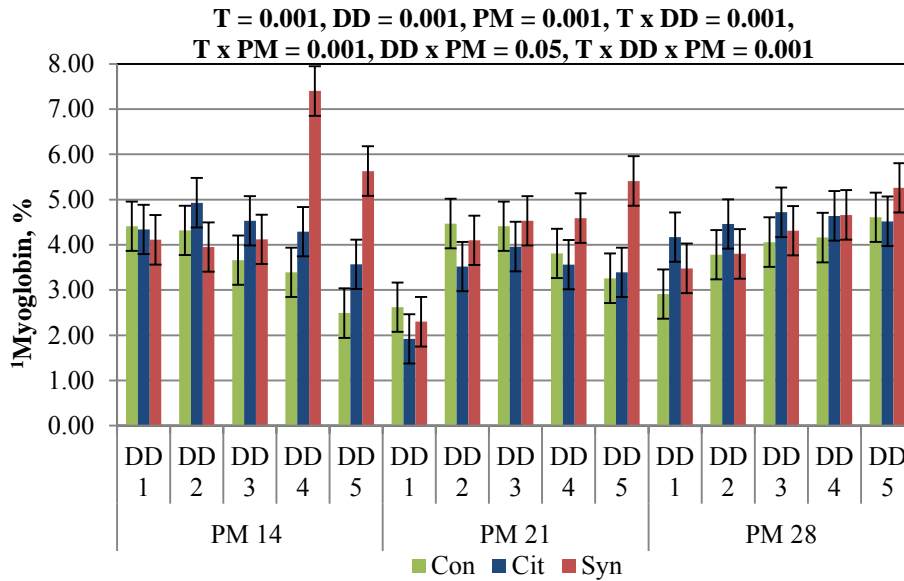


Figure 7. Least square means \pm SEM percent myoglobin instrumental values of striploin steaks by retail display day within postmortem ageing days. Treatments consisted of control (CON), citric acid (CIT), and BHA/BHT (SYN); T = treatment, DD = days of simulated retail display, and PM = days of postmortem aging; ¹Myoglobin percentage (fresh muscle pigment).

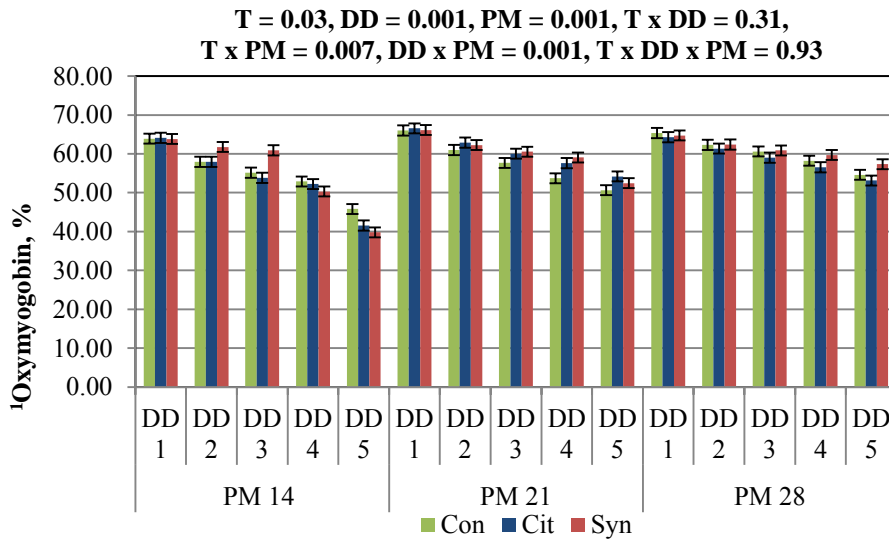


Figure 8. Least square means \pm SEM for lean oxymyoglobin instrumental values of striploin steaks by retail display day within postmortem ageing days. Treatments consisted of control (CON), citric acid (CIT), and BHA/BHT (SYN); T = treatment, DD = days of simulated retail display, and PM = days of postmortem aging; ¹Oxmyoglobin percentage (Oxygenated myoglobin pigment).

The effect of SYN application on striploin steaks was increasingly evident in the advanced periods of display day within all three postmortem periods. CIT application exhibited less of an effect on color stability when compared to SYN treatment. CIT application actually increased discoloration scores and browning scores during subjective color analysis when compared to CON results. The effect of SYN application was visibly noticeable throughout the simulated retail display setting as redness and color uniformity was extended for an additional 1-2 days when compared to CON and CIT treatments. When analyzing each postmortem aging periods from display days 1 through 5 SYN treatment maintained visual color scores while CON and CIT had significant spikes on display days 3 through 5.

The effect of SYN treatment on striploin steaks on instrumental a^* values showed the most significant trend in terms of meat redness as SYN maintained mean values of (16.54) compared to CON (14.66) and CIT (14.51).

Sensory. Sensory characteristics were evaluated on striploin steaks to compare treatment effects (Table 2). No effect of treatment on initial juiciness ($P = 0.815$), or sustained juiciness from treatment ($P = 0.768$) was evident from the panelist. There was also no effect from treatment on initial tenderness ($P = 0.281$) or sustained tenderness ($P = 0.769$). There was no effect of treatment on beef flavor intensity ($P = 0.463$), off flavor ($P = 0.158$) and overall acceptability ($P = 0.597$). Treatments of CON, CIT, and SYN did not produce any detectable differences in relation to the sensory properties of overall striploin steaks.

Several different aspects must be considered when the addition of any chemical compound or additive is made to a meat or food product. It must not influence the flavor profile of the item in any negative way and also must not change the juiciness or tenderness properties. During the cooking process chemical reactions occur between fatty acids and amino acids and their degradation products provide a large number of compounds that can contribute to meat flavor (Wood et al. 2004). Off odors and flavors are one of the most common negative sensory aspects developed during the ageing process of meat products. As with a study conducted by Camo et al. (2008), the direct addition of rosemary extract extended the fresh odor and color from eight to 13 days when compared to the control that contained no extracts. As seen with the results from this study there was no difference for any sensory attributes throughout the five-day display period for all three treatments. As determined by Morrissey et al. (1998), the typical shelf life of fresh meat is usually a time period of 3-5 days. Due to this information, there were no major off flavors produced since each postmortem aging period only had five days in a retail case environment. All sensory characteristics in the current study were similar across treatments. Sebranek et al. (2005) determined no unusual or uncharacteristic flavors were detected by panelist in a study where BHA/BHT was applied to pork sausage to determine its antioxidant effectiveness along with natural rosemary extract. Typical spices utilized in the production of pork sausage could have masked potential off flavors associated with synthetic antioxidants. In the present study, strip-loin steaks were not exposed to any spices or flavoring other than applied treatments of citric acid and BHA/BHT an acceptable determination could be made of sensory characteristics. Due to the very low concentration levels of antioxidants applied, citric acid 0.3% and BHA/BHT solution 0.08%, there were no detectable chemical flavors produced.

Table 2. LS Means \pm SE of Sensory Attributes of Striploin Steaks.

Attribute	Control	Citric Acid	Synthetic Acid
Average Initial Juiciness ^a	5.85 \pm 0.14	5.78 \pm 0.14	5.72 \pm 0.14
Average Sustained Juiciness ^b	5.56 \pm 0.13	5.51 \pm 0.13	5.43 \pm 0.13
Average Initial Tenderness ^c	6.20 \pm 0.24	5.70 \pm 0.24	5.78 \pm 0.24
Average Sustained Tenderness ^d	5.81 \pm 0.14	5.66 \pm 0.14	5.75 \pm 0.14
Average Flavor Intensity ^e	5.88 \pm 0.08	5.83 \pm 0.08	5.75 \pm 0.08
Average Off Flavor ^f	3.78 \pm 0.04	3.75 \pm 0.04	3.86 \pm 0.04
Average Overall Acceptability ^g	5.65 \pm 0.14	5.47 \pm 0.14	5.47 \pm 0.14

^a (Initial Juiciness) 1=Extremely Dry, 8=Extremely Juicy

^b (Sustained Juiciness) 1=Extremely Dry, 8=Extremely Juicy

^c (Initial Tenderness) 1=Extremely Tough, 8=Extremely Tender

^d (Sustained Tenderness) 1=Extremely Tough, 8=Extremely Tender

^e (Flavor Intensity) 1=Extremely Bland, 8=Extremely Intense

^f (Off Flavor) 1=Extreme Off Flavor, 4=None

^g (Overall Acceptability) 1=Dislike Extremely, 8=Like Extremely

Lipid Oxidation. Thiobarbituric reactive substances (TBA) were dependent on treatment x display day ($P = 0.013$; Figure 9). TBA levels increased with extended display day exposure for CON and CIT while SYN treatment maintained almost constant lower TBA values through display days 1 through 5. Since TBA is an indicator of lipid oxidation compounds this provides evidence that SYN treatment was not oxidizing as fast of a rate as other two treatments.

The typical oxidative deterioration of meat and meat products is caused by the degradation reactions of fats and pigments. Many of the oxidative processes that occur in meat can lead to other organoleptic deterioration in taste, color and texture. Antioxidants, including vitamin E which is commonly utilized in feedstuffs is a primary lipid soluble antioxidant in biological systems and breaks the chain of lipid peroxidation in cell membranes and prevents the formation of lipid hydroperoxides (Halliwell 1987). As determined with results from Sebranek et al. (2005), utilizing synthetic antioxidants such as BHA/BHT combinations are effective in maintaining low thiobarbituric reactive substance (TBARS) values of pre-cooked meat products. The effects of selected antioxidants from this study on the oxidative stability of strip-loin steaks in a retail case environment are presented (Figure 9). We found measures of lipid oxidation (TBARS) to increase with extended display day exposure and vacuum-packaged postmortem aging periods. TBARS increased in CON treatments and CIT treatments at an increased rate, when compared to SYN treatments especially in the later display day periods. As the data indicates SYN treatment had a relatively small increase from display day 1 through display day 5. This is a good indication that oxidation rates were reduced to a rate that could possibly increase the number of days before oxidative compounds are formed. Results from Sebranek et al. (2005) determined that BHA/BHT treatments was the most effective method in keeping TBARS at or below the baseline value of 0.5 mg/kg for up to 11 days in pork sausage. Data from the current study on display day 5 SYN has a mean value of 0.11 mg/kg as compared to CON values of 0.32 mg/kg for striploin steaks.

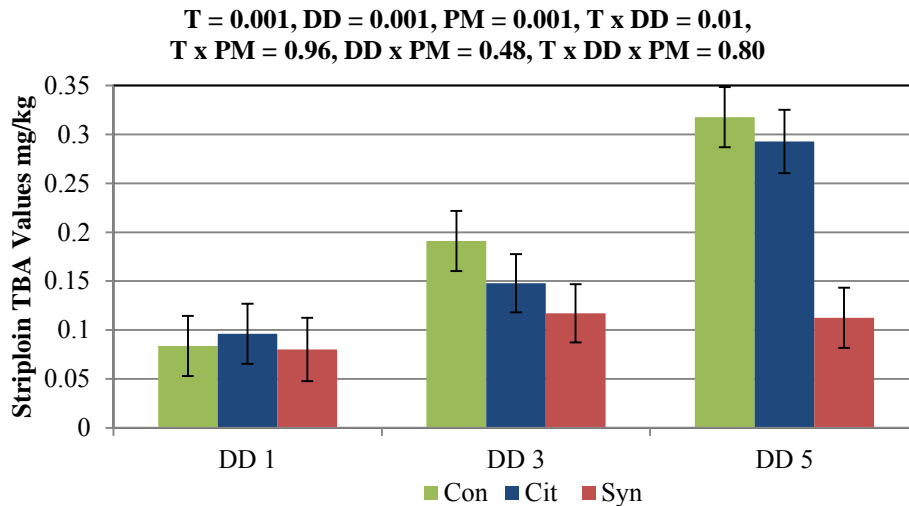


Figure 9. Least square means \pm SEM for thiobarbituric reactive substances values of striploin steaks by retail display day. Treatments consisted of control (CON), citric acid (CIT), and BHA/BHT (SYN); T = treatment, DD = days of simulated retail display, and PM = days of postmortem aging.

Master bag packaging extends the storage of the meat product but does not provide any noticeable benefits once the product is placed on the retail shelf. This is a major aspect in which antioxidant application could be utilized to extend the shelf life of whole muscle products once removed from their protected master packaging environment. The use of antioxidant application in the case-ready consumer market could be of significant impact as the industry reverts back to a traditional overwrap packaging system. Master packaging systems could include an antioxidant into the case ready package to extend the needed case life characteristics. Antioxidants including BHA and BHT are already utilized as food additives in many processed meat products throughout the processed meat industry. An antioxidant application system that could improve the shelf life and color stability of beef retail cuts could increase the profitability of the meat industry greatly. Steaks applied with the SYN treatment did maintain visual and objective color over an extended display day period with an increased postmortem aging period. The rate of lipid oxidation was also decreased with SYN treatment which suggests that retail case life could be extended. Given the results of this study, BHA and BHT applied to the surface of whole muscle beef cuts appears to be particularly effective for extending the shelf life when compared to current practices. The use of antioxidant application in the case-ready consumer market could prove useful as a greater amount of product is conveyed by traditional overwrap packaging systems. Master packaging systems could include an antioxidant application that would potentially increase desirable case life characteristics. Future research could examine effects of extended periods of display as the current study evaluated retail display for only five days within. Since there is such wide range and forms of both synthetic and natural antioxidants available, other potential antioxidant formulation could be considered. The overall consumer acceptance is not yet known and needs to be further addressed before industry applications are implemented.

REFERENCES

- American Meat Science Association (AMSA). 1991. Guidelines for meat color evaluation. Proc. Reciprocal Meat Conference.
- Braden KW, Blanton Jr. JR, Montgomery JL, Van Santen E, Allen VG, Miller MF. 2007. Tasco supplementation: effects on carcass characteristics, sensory attributes, and retail display shelf life. 85:754-768.
- Buege JA, Aust SD. 1978. Assay of lipid oxidation in muscle samples. *Methods in Enzymol.* 52:305, AP
- Camo J, Beltran JA, Roncales JA. 2008. Extension of the display life of lamb with an antioxidant active packaging. *Meat Science.* 80:1086-1091.
- Clydesdale FM. 1991. Color perception and food quality. *Journal of Food Quality.* 14(1), 61-74.
- Cross HR, Moen R, Stanfield M. 1978. Guidelines for training and testing judges for sensory analysis of meat quality. *Food Tech.* 32:48.
- Greene BE, Hsin IM, Zipser MW. 1971. Retardation of oxidative color changes in raw ground beef. *Journal of Food Science.* 36:940-942.
- Halliwell B. 1987. Oxidants and disease. Some new concepts. *FASEB J.* 1:358.
- Hunt MC. 1980. Meat color measurements. Proc. Recip. Meat Conf. 33:41.
- Jeremiah LE, Gibson LL. 1997. The influence of storage and display conditions on the retail properties and case life of display-ready pork loin roast. *Meat Science.* 47:17-27.
- Kerth CR, Blair-Kerth LK, Jones WR. 2003. Warner-bratzler shear force repeatability in beef longissimus steaks cooked with a convection oven, broiler, or clam-shell grill. *J Food Sci.* Vol. 68. 2:668-670.
- Littell RC, Milliken GA, Stroup WW, Wolfinger RD. 1996. SAS systems for mixed models. SAS Institute Inc., Cary, NC. USA.
- Mancini RA, Hunt MC. 2005. Current research in meat color. *Meat Science.* 71:100-121.
- Marth EH. 1998. Extended shelf life refrigerated foods. *Food Technology.* 52: 57-62.
- Morrissey PA, Sheehy PJA, Galvin K, Kerry JP, Buckley DJ. 1998. *Meat Science.* Vol. 49, No. Suppl. 1, S73-S86.
- Oussalah M, Caillet S, Salmieri S, Saucier L, Lacroix M. 2004. Antimicrobial and antioxidant effects of milk based film containing essential oils for the preservation of whole beef muscle. *J. Agric. Food Chem.* 52 (18)5598-5605.
- Resurreccion AVA. 2003. Sensory aspect of consumers choices for meat and meat products. *Meat Science.* 66:11-20.
- Sebreanek JG, Sewalf VJA, Robbins KL, Houser TA. 2005. Comparison of a natural rosemary extract and BHA/BHT for relative antioxidant effectiveness in pork sausage. *Meat Science.* 69:289-296.
- Smith GC, Morgan JB, Tatum JD. 1993. Marketing Vitamin E for meat-quality enhancement in the USA, Proc. Roche Vitamin E Workshop, Huffman. La Roche, AG, Luzern, Switzerland. pp 1-7.
- Steiner R, Belk KE, Smith GC. 2001. Determination of bloom time and case life of Nolan Ryan ground beef. Animal Science Research Report. Colorado State University, Fort Collins.
- United States Department of Agriculture (USDA). 1996. United States standards for grades of carcass beef. AMS, USDA, Washington, DC.

- United States Department of Agriculture (USDA). 1989. *Agricultural Statistics*. U.S Government Printing Office. Washington, DC.
- Williams SN, Frye TM, Frigg M, Schaefer DM, Scheller KK, Liv Q. 1992. Vitamin E. *Meat international*. 3 (2)22.
- Wood JD, Richardson RI, Nute GR, Fisher AV, Campo MM, Kasapidou E, Sheard PR and Enser M. 2004. Effects of fatty acids on meat quality: a review. *Meat Sci*. 66:2.