ASSESSMENT OF AMMONIUM HYDROXIDE, SALT AND CARBON MONOXIDE IN IMPROVING THE RETAIL DISPLAY CHARACTERISTICS, PALATABILITY AND CONSUMER ACCEPTANCE OF CASE READY RETAIL CUTS

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READY RETAIL CUTS

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CHAPTER I

INTRODUCTION

A major problem facing the meat industry is inconsistency in meat tenderness at the consumer level (Huff-Lonergan et al., 1995). Morgan (1991) stated that tenderness is a primary concern to the beef industry as it changes from a production led to a consumer driven industry. Due to large inconsistencies in tenderness as result of carcass composition, fat dressing, muscles, and location within a muscle, enhancement procedures have been developed to create more consistent product and upgrade others (Hamling et al., 2008).

Enhancement systems have been comprised of water, salt and phosphate. Injection with this solution has shown to increase water-holding capacity and tenderness (Vote et al., 2000; Lawrence et al., 2004; Baublits et al., 2006). Salt increases water holding capacity due to the swelling of muscle fibers because of changes in ionic strength (Offer and Trinick, 1983; Trout and Schmidt, 1987; Paterson et al., 1988). The introduction of chlorine ions into the lean creates a shift in pH, thus the electrostatic repulsive forces allow for more water to fill into the space and be held by capillary forces. The presence of phosphates reduces the chlorine concentration needed for maximum swelling, allowing more water to be held (Offer and Trinick, 1983).

New developments in enhancement technology have been developed over the years; one of the most recent ones is a patented process (Freezing Machines Inc. Dakota Dunes, SD) which employs an enhancement solution comprised of water, salt and ammonium hydroxide.

The objective of this solution or marinade is to increase the water holding capacity of meat, while eliminates the off-flavors associated with salt/phosphate enhancement. Several studies have shown the effectiveness of enhancement with salt and ammonium hydroxide. Nath et al. (2006) showed that pH of meat increased, purge loss increased, calculated moisture after cooking increased, and shear force decreased as pump percentage increased.

The objectives of this study were to evaluate retail display characteristics, palatability and consumer acceptance of case ready beef retail cuts enhanced with two different enhancement solutions one consisting of salt, ammonium hydroxide and the other one consisting of salt, ammonium hydroxide and carbon monoxide, compared against phosphate based enhancement solution.

CHAPTER II

REVIEW OF LITERATURE

Enhancement Systems

One of the main goals of the beef industry in the past years has been improving consistency of tenderness of beef products delivered to the consumer. Enhancement procedures have been developed to increase consumer satisfaction as well as to create a more consistent product.

Palatability accounts for the interaction of tenderness, juiciness and flavor. Of the three tenderness is the primary economic factor for beef palatability (Savell and Shackelford, 1992). Enhancement is done by injecting an aqueous solution into the muscle, and was developed to improve tenderness and consistency of meat products (Foote et al., 2004).

There are many advantages to the use of marinated products such as extending shelf life, controlling pathogenic bacterial growth, and preventing oxidation among others (Foote et al., 2004; McGee et al., 2003; Robbins et al., 2003). As a result, the beef industry is widely producing enhanced meat products to meet consumer demands (Hughes, 2002).

Enhancement systems have typically been comprised of water, salt and phosphate. Injection with this solution has shown to increase water-holding capacity and tenderness (Vote et al., 2000; Lawrence et al., 2004; Baublits et al., 2006).

Several studies have shown over and over that enhancement with salt and phosphates increase palatability traits (Trout and Schmidt, 1987; Vote et al., 2000; Lawrence et al., 2004; Baublits et al., 2006; Knock et al., 2006).

Salt increases water holding capacity due to the swelling of muscle fibers due to the changes in ionic strength (Offer and Trinick, 1983; Trout and Schmidt, 1987; Paterson et al., 1988). The presence of phosphates reduces the chlorine concentration needed for maximum swelling, allowing more water to be held (Offer and Trinick, 1983).

A method for the enhancement systems has been developed by Freezing Machines Inc. (Dakota Dunes, SD). This patented process (patent pending) employs a solution comprised of water, salt and ammonium hydroxide. These ingredients act in a way that increases the water binding capacity of meat, while eliminating off flavors associated with salt and phosphate addition.

Salt as described before creates electrostatic repulsion. Ammonium hydroxide aids in improving water binding capacity and contributes to a high pH of the solution (Hamling et al., 2008). The pH of beef is generally around 5.6, and the further away from this point, the more water can be bind between the myofibrillar proteins. Several studies (Everts et al., 2006a; Everts et al., 2006b; Hand et al., 2006; Nath et al., 2006) have shown the effectiveness of pH enhancement using salt and ammonium hydroxide.

Nath et al. (2006) showed that pH of meat increased, purge loss increased, and shear force decreased for all muscles tested (beef longissimus lumborum, gluteus medius, triceps brachii, biceps femoris, and psoas major) as pump percentage increased.

Consumer ratings were more favorable for enhanced steaks over controls (Everts el al., 2006a, b; Nath et al., 2006). According to Everts et al. (2006a) pH enhancement improved visual appearance of hams made from pale, average, and dark muscles and improved the eating quality of hams made from pale muscles.

Hamling et al. (2008) stated that there is no published data on the comparison of the two enhancement systems, although research has proven that enhancement is a feasible alternative to create a more palatable product for consumers.

Ammonium Hydroxide

The addition of ammonium to water results in the production of the ammonium ion (NH_4^+) and a hydroxide ion (Beattie 2008). Uses of ammonium hydroxide include the control or neutralization of acid components in foods (Beattie, 2008). In addition, the ammonium ion appears to have a significant antimicrobial effect aside from the pH change that is affected when added to meat products (Gupta et al., 1988). According to the FSIS Directive 7120.1 Amendment 18, attachment 1, ammonium hydroxide is considered a safe and suitable ingredient as a pH control agent in brine solutions for meat products. It also states that ammonium hydroxide can be sufficiently used for the purpose of achieving a brine solution with a pH of 11.4

Ammonium hydroxide is highly alkaline and is generally recognized as safe (GRAS) by FDA (21 CRF 184.1139) for consumption at lower levels and therefore makes a good prospect for an alternative means for raising meat pH and as an antimicrobial agent

Importance of tenderness

Tenderness is one of the most important attributes of beef, as well as juiciness and flavor. In addition, tenderness is a major concern for the beef industry as it changes from a production led to a consumer driven industry (Morgan, 1991). Multiple factors influence tenderness of meat. Belew et al. (2003) stated that the four general characteristics considered most important are, postmortem proteolysis, intramuscular fat or marbling, connective tissue, and the contractile state of the muscle, this factor plays a big role in the variation of tenderness within muscles in the carcass.

Huffman et al. (1996) stated that establishing a tenderness acceptability level for consumer markets could lead to new marketing schemes, for which a tenderness value is actually placed on a package for sale to restaurants or in the retail case.
Tenderness has been identified as the most important palatability attribute of meat and the primary determinant of meat quality (Dikeman, 1987; Miller et al., 1995). Studies have shown that consumers can differentiate beef that varies in tenderness and are willing to pay some level of premium for guaranteed tenderness (Boleman et al., 1997; Shackelford et al., 2001)

Color of Beef

Meat purchasing decisions are made by appearance of the meat more than any other quality factor because discoloration of meat is used as an indicator of freshness and wholesomeness (Mancini et al., 2005).

Color and shelf life play a big factor in consumer acceptability of enhancement systems, because the addition of salt promotes oxidation and early discoloration (Robbins, 2002). Myoglobin is the principle protein responsible for meat color, although other heme proteins such as hemoglobin and cytochrome C whom may also play a role in beef, lamb, pork, and poultry color. Oxygenation occurs when myoglobin is exposed to oxygen and is characterized by the development of a bright cherry-red color. As exposure to oxygen increases, the oxymyoglobin penetrates deeper beneath the meat surface. Depth of oxygen penetration and thickness of the oxymyoglobin layer depend on the meat temperature, oxygen partial pressure, pH, and competition for oxygen by other respiratory processes.

Discoloration results from oxidation of both ferrous myoglobin derivatives to ferric iron (Livingston & Brown, 1982). Although discoloration is often referred to as the amount of surface area covered by metmyoglobin, subsurface myoglobin forms also play a role in product appearance. This is because metmyoglobin beneath the surface (located between superficial oxymyoglobin and interior deoxymyoglobin) gradually thickens and moves towards the surface. Metmyoglobin formation depends on numerous factors including oxygen partial pressure, temperature, pH, meat reducing activity, and in some cases, microbial growth (Mancini et al 2005).

Carboxymyoglobin is a relevant chemical state of myoglobin because of the current increased interest in packaging with low levels of carbon monoxide (Luno, Roncales, Djenane, & Beltran, 2000; FDA, 2002, 2004; Hunt et al., 2004; Sorheim,

Nissen, Aune, & Nesbakken, 2001). Carbon monoxide can bind to the vacant 6th position of deoxymyoglobin and form a very bright-red color that is relatively stable. It appears that deoxymyoglobin is more readily converted to carboxymyoglobin than is oxy- or metmyoglobin. Nevertheless, carbon monoxide will slowly dissociate from myoglobin after carboxymyoglobin is exposed to atmospheres free of carbon monoxide.

Carpenter, Cornforth, and Whittier (2001) noted a strong association between color preference and purchasing intent with consumers discriminating against beef that is not red (i.e., beef that is purple or brown). Therefore, visual determinations are the gold standard for assessing treatment effects and estimating consumer perception.

Package type can influence red color perception. Meat packaged with film contact (PVC overwrap or vacuum) was perceived as more red than meat packaged with headspace (Carpenter et al., 2001). These authors also noted that panelist descriptions of color may depend on individual cognition when references are not used. Carpenter et al. (2001) concluded that consumer preference for bright-red colored beef overwrapped in PVC might slow industry's move toward central packaging (MAP and vacuum-skin packaging).

Gaseous atmosphere

Packing methods are used to increase the shelf life of fresh meats. Vacuum packing delays the growth of aerobic spoilage bacteria, molds, yeast, and slows lipid oxidation in fresh meats (Genigeorgis, 1985).Also, there are disadvantages that occur,

such as deformation of cuts by film tightening, temporary discoloration (Grau, 1983) and weight loss from purge (Zarate and Zaritzky, 1985).

Case ready meat cuts in a package contain high concentration of oxygen which provides the desired bright cherry-red color of fresh meat to consumers. However, oxygen promotes the growth of aerobic spoilage bacteria and development of oxidative rancidity in meats, which in turn decrease shelf life (Cole, 1986).

Carbon monoxide has shown to preserve meat color because the gas changes the myoglobin molecule into carboxymyoglobin, which is a very stable stage of the color molecule (Sorheim et al., 1999). Studies have shown that the introduction of carbon monoxide in a MAP actually improves beef and pork color, as well as other meat qualities (Clark and Lentz, 1973; Jayasingh et al., 2001; Sorheim et al., 1999, 2001).

Carbon Monoxide

Lean color is one of the first quality attributes consumers use to evaluate meat quality (Sorheim et al., 1999; Kenedy et al., 2004), therefore it plays a major role in purchase decisions. Modified atmosphere packaging (MAP) is a form of packaging that involves the removal of the normal atmosphere from the pack and replaces it with a single gas or a mixture of gasses different from normal atmosphere (Parry, 1993). With this process, shelf life of meat is maximized and maintains its attractive fresh appearance (Gill, 1996; Jayasingh et al., 2001; Sekar et al., 2006).

The gases most commonly used in MAP are oxygen, carbon dioxide, and carbon monoxide or combinations of any. Packaging with high concentration of oxygen provides

the desirable bright cherry red color of fresh meat to consumers, but this type of packing promotes the growth of aerobic microorganisms and development of oxidation in meats, which decreases shelf life (Cole, 1986).

Carbon dioxide is highly soluble in both water and oils, and when applied in meat systems is absorbed by the muscle and fat tissues until homogenized (Gill, 1988). Carbon dioxide has been shown to increase shelf life by some inhibition of spoilage bacteria and oxidative rancidity (Church and Parsons, 1995; Sorheim et al., 1999). However, high concentrations, of carbon dioxide in MAP, have been associated with a dark appearance in color of meat retail cuts (Gill and Jones, 1996). Carbon monoxide preserves meat color because the gas binds to myoglobin and produces a very stable bright red color, often associated with fresh meat (Sorheim et al, 1999). The inclusion of carbon monoxide to MAP improves and even stabilizes beef and pork color, as well as other meat qualities (Clark, Lentz, and Roth, 1976; Sorheim et al., 1999, 2001; Jayasingh et al., 2001).

The inclusion of carbon monoxide in MAP systems creates a concern, first off, carbon monoxide is a toxic gas; therefore, its use for food packing is not allowed in most countries (Luno et al., 2000). In addition, the stable bright cherry red color is maintained and may mask spoilage that occurs on fresh meat products (Eilert, 2005). The FDA (2004) decided that the color did not mask spoilage in fresh meats, where indicators of spoilage are color, offensive odors, and offensive flavors. Low levels of carbon monoxide are not inhibitory to the growth of spoilage bacteria (Sorheim et al., 1999). According to Eilert (2005), the use of carbon monoxide for color stability of fresh meats creates an

acceptable appearance and flavor for the consumer with optimal distribution shelf life for the retailer.

Retail Display/Shelf Life

Meat purchasing decisions are influenced by color more than any other quality factor, due to the fact that consumers observed discoloration as an indicator of freshness (Mancini and Hunt, 2005). Therefore, improving color stability of meat and extending its display life are very important concerns for retailers.

Retail beef being marketed in case ready format and consumer demand has led to the development of alternative methods for packing and processing (Behrends et al., 2003). Case ready products have improved consistency, reduce labor costs, reduce mark downs and throw away, and minimize food safety risks (McFarlane, 2006). According to Hamling et al. (2008) a case ready meat packing system must provide a bright cherry red, display-ready product with a long shelf life.

It is a well-known fact that aging of beef cuts promote improvements in tenderness during storage. When beef is aged in the open air, the period required to produce tenderness improvement often exceeds the period that meat can be held without bacterial spoilage (Ledward et al., 1970). Gill (1996) addressed the factors for the preservation of chilled meat should include the retention of an attractive, fresh appearance for the product displayed, retardation of bacterial spoilage, and minimization of exudates losses.

Lighting

Many research studies have shown that light is an important factor in discoloration of meat in retail trade (Lentz, 1971; McDougall et al, 1975; Bertelsen and Boegh-Soerensen, 1986), Ramsbottom et al. (1951) found fluorescent lighting at 60 to 200 foot-candle intensity resulted in no loss of beef color during 3d display. Kraft and Ayres (1954) observed a steady change in color of fresh beef from bright red to dull red during 2 d exposure of fresh beef to 30 to 40 foot-candles of fluorescent light. Marriott et al. (1967) found beef short loin steaks stored in the dark at -2^0 C for 10 d changed only slightly in visual color. Steaks kept less than 120 foot-candles of soft white fluorescent light discolored markedly after 5 d and continued to become progressively less desirable with longer display (Kropf, 2002).

Light types include incandescent, fluorescent, and metal halide which includes mercury vapor and high intensity sodium. Fluorescent lights vary widely in their influence on appearance of meat and their effect on display life and therefore should always be further identified by the special name of the lamp. Display lighting effects on the appearance or rate of discoloration of meat could result from: 1) temperature elevation at the meat surface, 2) photochemical effects, and/or 3) differences in color rendition because of different spectral energy distribution patterns.

Radiant heat from intense display lighting increases the temperature on the meat surface. Temperature of the meat surface increases proportionally with increased light intensity under both incandescent and deluxe cool white fluorescent lights. An estimated

1^0 C temperature rise has been reported for each 10 foot-candles of incandescent lighting for display cases with 1.98 cubic meters per minute air velocity. Higher temperatures at the meat surface speed up deteriorative influences on meat color such as oxidation and microbial metabolism and thus, temperature effects are critical (Kropf, 2002). Deluxe fluorescent lights radiate about one-fifth as much heat as incandescent lamps. Other specially designed lamps also radiate much less heat than incandescent, for equal foot-candle intensities of lighting.

Recent studies on cold chain variables indicate that there are benefits to maintaining ground beef at 0^0C (Mancini, 2001) during storage and display. This is in agreement with one major packer supplier of meat who emphasized critical importance of keeping temperatures no warmer than 0^0C. Storage at 0^0C, rather than at higher temperatures, carries over into longer display life, even when the product is displayed under warmer temperatures.

CHAPTER III

ASSESMENT OF AMMONIUM HYDROXIDE, SALT AND CARBON MONOXIDE IN IMPROVING THE RETAIL DISPLAY CHARACTERISTICS, PALATABILITY AND CONSUMER ACCEPTANCE OF CASE READY RETAIL CUTS

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ABSTRACT

Subprimals of chuck roll, IMPS # 118A, ribeye roll, IMPS # 112A, strip loin, IMPS # 180, round flats, IMPS #171G, outside round, IMPS # 171B, eye of round, IMPS # 171C, and sirloin caps, IMPS # 184D,(n = 5 of each subprimal) were enhanced with 3 different enhancement solutions; 1) containing salt and ammonium hydroxide, 2) containing salt, ammonium hydroxide and carbon monoxide, 3) containing salt and phosphates. The objective of this study was to determine the effects of pH enhancing subprimals on tenderness, palatability, and retail case life compared to a traditional enhancement solution containing salt and phosphates. Chuck steaks, chuck roast, ribeye steaks, strip loin steaks, top sirloin steaks, inside round steak, bottom round roast and eye of round steak (n = 9) were obtained, overwrapped and put into boxes for 10 d of dark storage to simulate transportation. Subjective color scores during retail case life showed similar muscle color as phosphate enhanced chuck steaks, chuck roast, top sirloin steaks, eye of round steaks, bottom round roast ($P > 0.05$). For middle meats as ribeye steak and strip

loin steak, muscle color and percent discoloration of pH enhancement performed better than control samples ($P < 0.05$). Sensory panelist did not found a difference between treatments in ribeye steaks, strip loin steaks, inside round steaks ($P > 0.05$). However for chuck steaks and chuck roast pH enhancement showed to have an effect in tenderness ($P < 0.05$). Therefore more research needs to be conducted to further improve the effects of pH enhancement solutions on color stability as well as for sensory characteristics of case ready retail cuts.

Keywords: enhancement, palatability, shelf life, tenderness, retail cuts.

INTRODUCTION

Value added efforts in the beef industry go as far back as the late 1970s. Today, value added stems beyond labels and includes practices such as enhancement, and packaging methods for meat. Enhancement of current products presents a significant opportunity to increase consumer demand and returns to beef producers. Enhancement systems have been comprised of water, salt and phosphate. Injection with this solution has shown to increase water-holding capacity and tenderness (Vote et al., 2000; Lawrence et al., 2004; Baublits et al., 2006).

New developments in enhancement technology have been developed over the years; one of the most recent ones is a patented process (Freezing Machines Inc. Dakota Dunes, SD) which employs an enhancement solution comprised of water, salt and ammonium hydroxide.

The objective of this solution or marinade is to increase the water holding capacity of meat, while eliminates the off-flavors associated with salt/phosphate enhancement. Several studies have shown the effectiveness of enhancement with salt and ammonium hydroxide. Nath et al. (2006) showed that pH of meat increased, purge loss increased, calculated moisture after cooking increased, and shear force decreased as pump percentage increased.

The objectives of this study was to determine shelf life, palatability traits, and color stability on case ready cuts enhanced with a solution containing water, salt, ammonium hydroxide, and carbon monoxide, compared against phosphate based enhancement solution

MATERIAL AND METHODS

Experimental design

There were five enhancement treatments: Low (LOW) which injected percentage was approximately 60% of the recommended by Beef Products Inc. (BPI) technicians, Recommended (REC) injection level was based on preliminary results obtained at BPI, Carbon Monoxide (CO) same level of injection used in recommended plus enough carbon monoxide so final product would result in less than 0.4% of carbon monoxide in finished product, Topical treatment (TOP) consist of no injection of product only topical overspray of solution, and Control (CON) which consist of product obtained at a local Wal-Mart store. Subprimals (n = 7) were randomly assigned to each treatment.

Treatments were compared for color stability during retail display, and palatability attributes via trained taste panel.

Raw meat materials

Subprimals of chuck roll , rib eye roll, strip loin, round flats, outside round, eye of round and sirloin caps (n = 5 of each) were obtained from National Beef Packing Co. Subprimals (2-3 d postmortem) were randomly assigned to each treatment. Preparation of the samples took place at the Beef Products Inc. facility in Dakota City, Nebraska.

Preparation and injection of the enhancement solution

The solution or marinade comprised of water, salt, ammonium hydroxide, and carbon monoxide, which was prepared by Beef Products Inc. (BPI) technicians. Solution contained 1% sodium chloride and sufficient ammonium hydroxide to make the brine pH 11.4. Enhancement solution for one of the treatments, carbon monoxide (CO), contained carbon monoxide formulated into the solution to have less than 0.4% of carbon monoxide in the finished product. This is patented technology from Freezing Machines Inc., Dakota Dunes, SD.

Subprimals assigned to each treatment (LOW, REC, CO) were unpacked and initial weight was taken. Subprimals were injected by a Fomaco injector (Model #FGM-88SW, Denmark). Once injected, subprimals were weighed after 5 minutes to determine

the actual treatment distribution. Subprimals assigned to topical treatment were not injected.

Cutting procedures

Subprimals were cut into steaks, parallel to the cut surface, to a thickness of 2.54 cm. nine steaks were cut for each treatment. Chuck Roast followed same cutting procedure to a thickness of 5.08 cm. Bottom Round Roast were cut into a thickness of 10.16 cm. Order of each steak and roast was maintained from this point on through the whole study. Steaks and roast were trimmed to 0.635 cm of external fat and the muscle of interest intact (ribeye steak, strip loin steak, top sirloin steak, eye of round steak, chuck steak, inside round steak, chuck roast, and bottom round roast).

Packaging procedures

Steaks and roasts were placed in Styrofoam trays and overwrapped with a polyvinyl chloride film (PVC), to match retail display characteristics, and placed into boxes at Beef Products, Inc. (Dakota City, NE) prior to shipping to Oklahoma State University, Stillwater. Boxes were shipped to the Food and Agricultural Product Center at Oklahoma State University on the following day. Boxes were stored in a cooler (-1°C) for 10 d.

Assignment of steaks

For each treatment eleven steaks or roasts were received and distributed as follow: the first seven steaks or roasts were used for retail display and color evaluation, and four steaks or roasts were used for sensory attributes.

Subjective Color Determination

Following a 10 d period to simulate transportation and distribution, all steaks and roasts were displayed in a commercial retail display case for 7 d under cool-white fluorescent light (1,600 to 1,900 lux) at 4°C. Samples were evaluated every 12 h by a trained panel (n = 5). Measured characteristics according to the Guidelines for Meat Color Evaluation (Reciprocal Meat Conference, 1991) were lean color (8 = bright cherry red to 1 = extremely dark brown color), percent discoloration (7 = none or 0% to 1 = complete or 100%), overall appearance (8 = extremely desirable to 1 = extremely undesirable) served as an indicator of acceptability of the retail products (Appendix B, sample ballot).

A total of 440 retail samples, seven of each treatment per cut, were evaluated during 7 d of simulated retail display, for all three shelf-life categories.

Sensory

Sensory analysis was conducted according to the Research Guidelines for Cookery, Sensory Evaluation and Instrumental Tenderness Measurements of Fresh Meat

(AMSA, 1995). The steaks were cooked to a medium degree of doneness (70°C) using a Lincoln® conveyorized electronic oven (model 1132-00-A). After cooking, steaks were transported to the test kitchen to be cut into cubes for serving. Each panelist had a ballot containing five different categories, juiciness, sustained juiciness, tenderness (first impression and overall impression), and amount of connective tissue. The juiciness trait was evaluated using a 8 point scale; 8 = extremely juicy to 1 = extremely dry. Tenderness also was evaluated on an 8point scale; 8 = extremely tender to 1 = extremely tough. Amount of connective tissue; 1 = none to 8 = abundant. Panelist also evaluated the following tastes/flavors: cooked beef flavor, painty fishy flavor and livery metallic flavor. Each flavor category was evaluated using a 3 point scale; 3 = Strong to 1 = not detectable. All of the results from the panelist (n = 8) were averaged to get a mean score for each category. Training of panelists for tenderness, juiciness, and connective tissue is outlined in the Research Guidelines for Cookery, Sensory Evaluation, and Instrumental Tenderness Measurements of Fresh Meat (AMSA, 1995). Flavor training was conducted in sessions in which meat was prepared to give either strong, slightly detectable, or non-detectable flavors of beef (cooked beef), salt, soapy (phosphate) and livery (metallic). Each of the 8 panelists took part in 2 taste panel sessions of 9 samples (n = 18) per day throughout the course of 10 d. Therefore, panelists received samples from 1 steak from each cut for all five enhancement treatments.

Statistical Analysis

Data were analyzed using generalized linear model (PROC GLM); (SAS 2003). Results for subjective color were analyzed using time as a repeated measure, sample as the subject, and treatment as the fixed effect. Sensory traits included treatment as the fixed main effects, and panelist and identification number as the random effects. All tests were conducted at the nominal significance level of $\alpha = 0.05$.

RESULTS AND DISCUSSION

Retail Shelf Life.

Ribeye steaks results are showed in Figures 3.1, 3.2 and 3.3. The comparison of LOW, Recommended (REC), Carbon Monoxide (CO), Topical (TOP) and Control (CON) steaks from d 0 retail display to d 6 retail display. Steaks were placed into retail display after 10 d of dark storage at 4°C, so d 0 retail display is actually d 11 of storage after packaging of steaks. For muscle color there was a significant ($P < 0.05$) treatment effect, where LOW ribeye steaks showed to have a more desirable color display and overall acceptance as well as less discoloration than the remaining of the treatment groups Figures 3.1, 3.2 and 3.3.

Meat color of ribeye steaks decreased significantly throughout the entire 7 d of retail display (Figure 3.1). Lawrence and others (2004) suggested that aside from the muscle darkening effects from high pH caused by the brine solution, the proxidant

activity of salt likely decreased the color stability of steaks treated with phosphate, salt, and natural flavorings.

As anticipated, lean surface discoloration of ribeye steaks for all treatments was minimal at the beginning of retail display. As retail time increases, surface discoloration increased for all treatments started at d 1 with no discoloration to slight discoloration (scores of 1 and 2 respectively), REC and CON ribeye steaks in d 2 showed slight discoloration (scores of 2), compared to the ribeye steaks from the LOW, CO and TOP treatments groups. It should be mentioned that these same treatments (LOW, CO and TOP) displayed less surface discoloration than the other treatment groups ($P < 0.05$).

Overall appearance of all ribeye steaks remained acceptable until d 5 of retail display. However, CON ribeye steaks were significantly less desirable in terms of overall acceptability ($P < 0.05$). In fact, the time of retail display having acceptable ratings was approximately 38 h and 110 h for control (CON) compared to the remaining treatments, respectively.

Strip loin steaks showed very similar characteristics in color stability and discoloration as ribeye steaks, as shown in Figures 3.4 through 6. Initially, TOP treatment showed higher lean color scores ($P < 0.05$) than the remaining of the treatments (Figure 3.4). However, no differences existed in lean color ratings for CO, CON, REC and LOW as retail display time increased.

Percent discoloration for strip loin steaks was observed to be not significant between treatments ($P > 0.05$) achieving small to modest discoloration scores until d 7 of

retail display. Recommended strip loin steaks displayed the most surface discoloration ($P < 0.05$) as showed in Figure 3.5. These findings can be possibly explained as the interaction of the enhancement solution to bacterial growth as described by Hamling (2008) were plate counts increased as dark storage time and retail display time increased. For overall appearance of strip loin steaks, CO, TOP and LOW treatments consistently were rated more desirable ($P < 0.05$) than CON and REC strip loin steaks (Figure 3.6). This initial difference that was observed remained consistent as display time increased.

Has to be noted that chuck steaks enhanced with ammonium hydroxide were considerably darker, in terms of lean color, than the rest of the steaks evaluated in this study (Figure 3.7). Hamling et. al., (2008) mentioned that regardless of dark storage period, chuck steaks got darker as retail display time progressed. Chuck steaks from the REC group were observed to be slightly bright cherry red (score of 5) as the rest of the treatments were evaluated as slightly dark cherry red (scores of 4) with no significant differences ($P > 0.05$).

Percent discoloration for chuck steaks was observed to increased gradually, no difference between treatments was observed with exception of CON which displayed considerably less discoloration ($P < 0.05$), than the rest of the treatments (Figure 3.8), this findings are surprising and unexplainable in that the CON samples were more consistent in terms of lower surface discoloration ratings. As a result of improved surface discoloration stability, CON chuck steaks improve its overall appearance values as retail display time increased (Figure 3.9).

Chuck roast muscle color for TOP and CON treatments showed significant differences ($P < 0.05$) as TOP exhibited bright cherry red (score of 7) and slightly cherry red (score of 4) lean color ratings, respectively at beginning of retail display (d 1). It should be noted that as retail display time increased, all of treatments, with exception of CON chuck roasts, began the retail display period with high lean color ratings with a slow, linear decrease in lean color darkening (Figure 3.10). Carbon monoxide (CO) samples showed unacceptable ratings and remained the same throughout retail display.

Summarized in Figure 3.12 shows the impact of various enhancement treatments on chuck roast overall appearance. Initial display times (d 1) revealed that TOP chuck roasts were more desirable ($P < 0.05$) compared to remaining treatments. After 60 h of display, all treatments remained stable with the exception of CO chuck roast in which they displayed the least desirable overall appearance rating (Figure 3.12). Toward the termination of the display period (~108 h), CON chuck roast remained more desirable than other treatments.

Eye of round steaks were difficult to analyze due to their natural metallic shine acquired following enhancement. In this study, significant differences ($P < 0.05$) were found in lean color and surface discoloration, for lean color CON eye of round steaks showed to be the least acceptable ($P < 0.05$) the rest of the treatments showed similar scores as show in Figure 3.13. In terms of surface discoloration CO showed a rapid increase after 24 h being the least acceptable treatment ($P < 0.05$). As for overall

appearance no significant differences were found ($P > 0.05$) with similar decrease in acceptability at 48 h of retail display.

Top sirloin steaks have historically been one of the most highly utilized, as well as most challenging in terms of retail display compared to other beef muscle cuts. In this investigation none of the tested enhancement treatments appeared to be very successful in terms of extending shelf life based on lean color stability (Figure 3.16). In all cases, the obtained case life capacity of top sirloin steaks average of approximately 24 h.

In the case of top sirloin steaks (Figure 3.17), TOP treated products were discolored (~20-40%) going into the retail case. Steaks remained discolored more than the rest of the treatments throughout the retail testing time. The remaining treatments reacted similarly ($P > 0.05$) in the area of surface discoloration of top sirloin steaks (Figure 3.17).

Top sirloin steaks of LOW were found to have significant overall acceptability improvements ($P < 0.05$) during the duration of the 7 d display period (Figure 3.18). On the other end of the scale, topical treated sirloin steaks were consistently the worst performing ($P < 0.05$) treatment compared to the overall acceptability of remaining enhanced treatments.

For inside round steaks, the initial 48 h of retail display all treatments reacted in a similar ($P > 0.05$) manner (Figure 3.19). However, from 60 h of display through 144 h, inside round steaks treated with REC or CON had brighter, more desirable lean color compared to the remaining inside round counter parts.

From a discoloration stand point, inside round steaks treated with the TOP methods had more surface off coloring (i.e. browning) throughout retail display (Figure 3.20). The remaining inside round steak treatments performed in a similar manner ($P > 0.05$) throughout retail display.

As a result of inferior lean color and surface color discoloration, TOP treated inside round steaks had the least desirable overall appearance ($P < 0.05$) from the initial hour of retail display. It appeared that during later retail times (> 84 h), CON inside round steaks had numerically higher appearance values (Figure 3.21).

Bottom round roast were difficult to objectively score their respective lean color in that the nature of this cut having a thick layer of subcutaneous fat covering a majority of the cut (Figure 3.22). So from a lean color standpoint, few changes of lean color could be observed. Similar to the inside round steaks, bottom round cuts treated with TOP discolored faster ($P < 0.05$) than other bottom round roast treatments (Figure 3.23). It appeared that CON bottom round cuts remained the most consistent in terms of surface discoloration during retail display. The additive differences in lean color and surface discoloration allowed CON bottom round cuts to remain more consistent and in turn had higher overall appearance (Figure 3.24) than remaining bottom round roasts.

Sensory Panel

One of the major interests which surround enhanced meat products is the marked improvement in tenderness of these products. In this project the LOW and REC

enhancement process improved tenderness (first and overall) of round cuts when compared to TOP and CON round cuts (Table 3.1). For eye of round steaks, improvements in tenderness were observed for LOW, REC and CO treatment groups (Table 3.2). Again topical treatment of eye of round steaks was much tougher ($P < 0.05$) than the LOW and REC samples. Surprisingly, LOW and CON eye of round steaks displayed high ratings for salty flavor compared to the other treatments.

One of the issues associated with enhanced beef is that some negative flavor profiles (salty, fishy, and livery) can accompany the improvements in tenderness. For round cuts (Table 3.1), as expected, LOW and REC samples were rated as having higher amounts of salt compared to other treatment groups. Additionally, CO bottom round cuts exhibited higher ($P < 0.05$) livery notes than REC or CON counterparts.

As for top sirloin steaks, the LOW treated steaks were the most tender compared to all remaining treatments (Table 3.2). All remaining treatments (REC, CO, TOP, and CON) performed in a similar manner ($P > 0.05$) in terms of tenderness, juiciness and connective tissue presence. These findings were similar to Hamling and others (2008) where top sirloin steaks showed a greatest improvement in tenderness and juiciness after pH enhancement treatment.

For ribeye steaks as expected REC treatment steaks received higher ratings in tenderness (first impression) as compared to the other treatment groups ($P < 0.05$). Also LOW, REC and CON were more salty than CO and TOP (Table 3.3). In terms of juiciness all treatments performed very similar

As for strip loin steaks similar results were noted for all treatment groups as described in Table 3.3. Even when no statistical difference was noted, it has to be mentioned that REC treatment strip loin steaks received higher values in terms of juiciness, tenderness and connective tissue presence Parson and other (2009) concluded that strip loins enhanced with ammonium hydroxide as well with typical enhancement solution (salt and phosphates) had no significant differences in terms of juiciness, tenderness and connective tissue amount.

For chuck steaks LOW treatment received the lowest ratings in terms of tenderness and connective tissue amount as compared to CO which received the highest ratings as describes in Table 3.4. These findings are similar to Molina and others (2005), where the use of enhancement solution via needle pumping procedure might be ideal in the beef chuck to improve palatability traits. Also LOW was noted to have a higher note of cooked beef ($P < 0.05$) than the rest of the treatment groups (REC, CO, TOP, CON).

In the case of chuck roast CO treatment was perceived as been tougher than LOW as seen in Table 3.4. In the case of juiciness no differences were found. It has no be noted that LOW, REC, CO, TOP and CON performed in similar manner in terms of flavor characteristics.

CONCLUSION

Data collected in this study shows that enhancement with ammonium hydroxide improves the sensory attributes, juiciness, tenderness and flavor of beef steaks and roasts;

this change could be explained as the beef fibers are displaced from its isoelectric point as pH of the enhancement solution increases.

Differences found in subjective color determination suggests, that ammonium hydroxide enhancement solution reacts differently with the muscle to be enhanced, where ammonium hydroxide enhancement showed a slighter darker color than control or phosphate enhanced steaks. However, percent discoloration for ammonium hydroxide enhanced steaks was less than control or phosphate enhanced steaks, therefore lasting between 24 to 36 h longer than control or phosphate enhanced steaks which started showing discoloration at 36 h of retail display.

With the completion of this study, areas of research are needed to further understand ammonium hydroxide as part of an enhancement solution and its interaction with other ingredients to further help color stability, water holding capacity and flavor characteristics in the beef industry.

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TABLE 3.1. Least Square Means for trained taste panel scores for beef inside round steaks and bottom round roast enhanced with various moisture enhancement treatments. LOW = 60% injection of recommended level, REC = recommended injection level, CO = recommended injection level with .4% carbon monoxide incorporated into solution, TOPICAL = no injection only topical overspray of recommended solution, CONTROL = salt and phosphate enhancement solution.

Treatment	Initial Juiciness[1]	Sustained Juiciness[1]	Tenderness (first Impression)[1]	Tenderness (Overall Impression)[1]	Connective Tissue[1]	Flavors[2]			
						Cooked Beef	Salty	Painty / Fishy	Livery / Metallic
Inside Round									
LOW	5.25	4.88	6.06^{a}	6.19^{a}	1.06	1.06	2.06^{a}	1.81^{b}	6.00^{a}
REC	6.13	5.63	5.94^{a}	6.00^{a}	1.06	1.00	2.00^{a}	2.00^{ba}	5.75^{a}
CO	5.33	5.03	5.51^{ab}	5.44^{ab}	1.21	1.04	1.58^{ba}	2.13^{ba}	5.25^{a}
TOPICAL	3.63	3.63	4.00^{b}	3.50^{c}	1.00	1.13	1.00^{b}	2.50^{a}	4.00^{b}
CONTROL	4.13	4.00	4.13^{b}	4.13^{bc}	1.13	1.00	1.123^{b}	2.50^{a}	4.00^{b}
SE	0.87	1.00	0.21	0.18	0.07	0.00	0.07	0.03	0.06
Bottom Round Roast									
LOW	5.69	5.31	5.31^{ab}	5.69^{ab}	1.19^{ba}	1.06	1.50^{b}	2.00^{c}	4.50^{ba}
REC	5.56	4.88	5.75^{a}	6.19^{a}	1.00^{b}	1.00	1.81^{a}	2.25^{b}	5.38^{a}
CO	5.38	4.50	5.19^{ab}	5.44^{ab}	1.25^{a}	1.06	1.38^{cb}	2.38^{ba}	5.13^{ba}
TOPICAL	5.63	5.31	3.81^{b}	4.56^{c}	1.06^{ba}	1.06	1.00^{d}	2.44^{a}	3.69^{b}
CONTROL	5.00	4.63	5.00^{ab}	4.88^{bc}	1.00^{b}	1.13	1.13^{cd}	2.00^{c}	4.88^{ba}
SE	0.11	0.12	0.26	0.07	0.00	0.01	0.01	0.00	0.28

^{a,b,c,d} Means, in the same column, that do not have common superscripts differ ($P < 0.05$)

[1] Based on a 8 point scale: 8 = extremely juicy, tender, no connective tissue; 1 = Extremely dry, tough, abundant amount of connective tissue.

[2] Based on a 3 point scale: 3 = strong off flavor; 2 = slightly detectable; 1 = not detectable.

TABLE 3.2. Least Square Means for trained taste panel scores for beef eye of round steaks and top sirloin steaks enhanced with various moisture enhancement treatments. LOW = 60% injection of recommended level, REC = recommended injection level, CO = recommended injection level with .4% carbon monoxide incorporated into solution, TOPICAL = no injection only topical overspray of recommended solution, CONTROL = salt and phosphate enhancement solution.

						Flavors[2]			
Treatment	Initial Juiciness[1]	Sustained Juiciness[1]	Tenderness (first Impression)[1]	Tenderness (Overall Impression)[1]	Connective Tissue[1]	Cooked Beef	Salty	Painty / Fishy	Livery / Metallic
Eye of Round									
LOW	5.84^{a}	5.75a	6.50^{a}	6.59^{a}	6.59^{a}	1.72^{bc}	2.16^{a}	1.06	1.09^{ba}
REC	5.19^{ab}	4.92^{ab}	6.25^{ab}	6.19^{ba}	6.09^{ba}	1.99^{ba}	1.69^{ba}	1.03	1.06^{b}
CO	4.84^{bc}	4.50^{b}	5.19^{bc}	5.25^{bc}	5.31^{bc}	2.03^{ba}	1.50^{b}	1.19	1.03^{b}
TOPICAL	4.40^{c}	4.02^{b}	4.30^{c}	4.52^{c}	4.53^{c}	2.20^{a}	1.17^{b}	1.19	1.16^{ba}
CONTROL	5.17^{ab}	4.81^{ab}	5.38^{bc}	5.51^{bac}	5.53^{bac}	1.54^{c}	2.12^{a}	1.06	1.31^{a}
SE	0.15	0.35	0.39	0.39	0.39	0.04	0.09	0.01	0.02
Top Sirloin									
LOW	5.94^{a}	5.69^{a}	7.13^{a}	7.06^{a}	7.13^{a}	1.50^{d}	2.50^{a}	1.06	1.00
REC	4.75^{b}	4.44^{b}	5.56^{b}	5.69^{b}	5.69^{b}	1.69^{dc}	1.75^{b}	1.00	1.00
CO	4.93^{ab}	4.88^{ab}	6.00^{ab}	6.00^{ba}	5.99^{ba}	1.94^{bc}	1.54^{b}	1.13	1.25
TOPICAL	5.00^{ab}	4.63^{ab}	4.94^{b}	5.00^{b}	5.00^{b}	2.25^{a}	1.25^{b}	1.19	1.38
CONTROL	4.06^{b}	3.88^{b}	5.13^{b}	5.38^{b}	5.63^{b}	2.06^{ba}	1.38^{b}	1.06	1.31
SE	0.19	0.21	0.20	0.22	0.27	0.01	0.04	0.02	0.02

^{a,b,c,d} Means, in the same column, that do not have common superscripts differ ($P < 0.05$)

[1] Based on a 8 point scale: 8 = extremely juicy, tender, no connective tissue; 1 = Extremely dry, tough, abundant amount of connective tissue.

[2] Based on a 3 point scale: 3 = strong off flavor; 2 = slightly detectable; 1 = not detectable.

TABLE 3.3 Least Square Means for trained taste panel scores for beef ribeye steaks and strip loin steaks enhanced with various moisture enhancement treatments. LOW = 60% injection of recommended level, REC = recommended injection level, CO = recommended injection level with .4% carbon monoxide incorporated into solution, TOPICAL = no injection only topical overspray of recommended solution, CONTROL = salt and phosphate enhancement solution.

Treatment	Initial Juiciness[1]	Sustained Juiciness[1]	Tenderness (first Impression)[1]	Tenderness (Overall Impression)[1]	Connective Tissue[1]	Flavors[2]			
						Cooked Beef	Salty	Painty / Fishy	Livery / Metallic
Ribeye									
LOW	6.19^{a}	5.81^{a}	6.88^{b}	7.00^{a}	7.13^{ba}	1.31^{c}	2.63^{a}	1.13	1.00^{c}
REC	6.00^{ab}	5.81^{a}	7.50^{a}	7.38^{a}	7.38^{a}	1.38^{c}	2.38^{ba}	1.25	1.00^{c}
CO	5.44^{ab}	5.13^{ab}	6.63^{bc}	6.56^{b}	6.81^{bc}	1.44^{c}	1.63^{c}	1.25	1.13^{bc}
TOPICAL	5.25^{b}	4.75^{b}	6.00^{d}	6.19^{b}	6.63^{c}	2.38^{a}	1.06^{d}	1.06	1.31^{ba}
CONTROL	6.00^{ab}	5.63^{ab}	6.19^{cd}	6.25^{b}	6.56^{c}	1.63^{b}	2.00^{bc}	1.31	1.38^{a}
SE	0.10	0.13	0.05	0.03	0.03	0.00	0.05	0.05	0.01
Strip loin									
LOW	5.44	5.19	5.44	5.56	5.94	1.81	1.63	1.31	1.13
REC	6.00	5.75	7.06	7.19	7.19	1.50	2.31	1.25	1.00
CO	4.63	4.5	6.00	5.88	6.25	1.63	2.06	1.19	1.00
TOPICAL	5.06	4.88	6.63	5.56	5.88	1.94	1.75	1.13	1.25
CONTROL	5.63	5.25	5.88	6.25	6.50	2.13	1.38	1.25	1.38
SE	1.04	1.03	1.42	2.52	2.04	0.21	0.51	0.01	0.04

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

[1] Based on a 8 point scale: 8 = extremely juicy, tender, no connective tissue; 1 = Extremely dry, tough, abundant amount of connective tissue.

[2] Based on a 3 point scale: 3 = strong off flavor; 2 = slightly detectable; 1 = not detectable.

TABLE 3.4. Least Square Means for trained taste panel scores for beef chuck steaks and chuck roast enhanced with various moisture enhancement treatments. LOW = 60% injection of recommended level, REC = recommended injection level, CO = recommended injection level with .4% carbon monoxide incorporated into solution, TOPICAL = no injection only topical overspray of recommended solution, CONTROL = salt and phosphate enhancement solution.

Treatment	Initial Juiciness[1]	Sustained Juiciness[1]	Tenderness (first Impression)[1]	Tenderness (Overall Impression)[1]	Connective Tissue[1]	Flavors[2]			
						Cooked Beef	Salty	Painty / Fishy	Livery / Metallic
Chuck Steak									
LOW	5.31^{ab}	5.13^{b}	4.50^{c}	4.44^{d}	4.19^{b}	2.06^{b}	1.19	1.19^{a}	1.13^{b}
REC	5.44^{ab}	5.13^{b}	6.00^{b}	5.88^{c}	5.75^{a}	1.88^{a}	1.75	1.06^{b}	1.19^{b}
CO	5.63^{a}	5.31^{ab}	6.75^{a}	6.81^{a}	6.75^{a}	1.81^{a}	1.38	1.06^{b}	1.06^{b}
TOPICAL	5.63^{a}	5.63^{ab}	6.00^{b}	6.00^{bc}	5.88^{a}	1.56^{a}	1.19	1.50^{a}	1.56^{a}
CONTROL	5.25^{b}	5.25^{ab}	6.25^{b}	6.50^{ab}	6.38^{a}	1.63^{a}	1.50	1.50^{a}	1.63^{a}
SE	0.01	0.02	0.01	0.35	0.17	0.04	0.06	0.01	0.01
Chuck Roast									
LOW	6.25	6.19	6.63^{a}	6.31^{a}	5.88^{a}	1.88	1.63^{a}	1.06	1.06^{ba}
REC	6.25	5.88	6.19^{ab}	5.94^{a}	5.25^{ba}	2.00	1.56^{a}	1.06	1.13^{ba}
CO	5.38	4.81	4.38^{c}	4.38^{b}	4.44^{b}	2.44	1.13^{b}	1.00	1.00^{b}
TOPICAL	5.69	5.50	5.81^{ab}	5.44^{a}	5.13^{ba}	2.38	1.00^{b}	1.13	1.19^{ba}
CONTROL	5.63	5.63	5.50^{b}	5.50^{a}	5.25^{ba}	2.00	1.38^{ba}	1.13	1.25^{a}
SE	0.12	0.21	0.11	0.10	0.13	0.06	0.02	0.00	0.00

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

[1] Based on a 8 point scale: 8 = extremely juicy, tender, no connective tissue; 1 = Extremely dry, tough, abundant amount of connective tissue.

[2] Based on a 3 point scale: 3 = strong off flavor; 2 = slightly detectable; 1 = not detectable.

Figure 3.1 Subjective lean color stability evaluation of various moisture enhancement treatments of ribeye steaks displayed over time. LOW = 60% injection of recommended level, REC = recommended injection level, CO = recommended level with .4% carbon monoxide incorparated into the solution, TOPICAL = no injection only topical overspray of recommended solution, CONTROL = salt and phosphate enhancement solution. Lean color scale: 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, (n = 7 observations/mean).

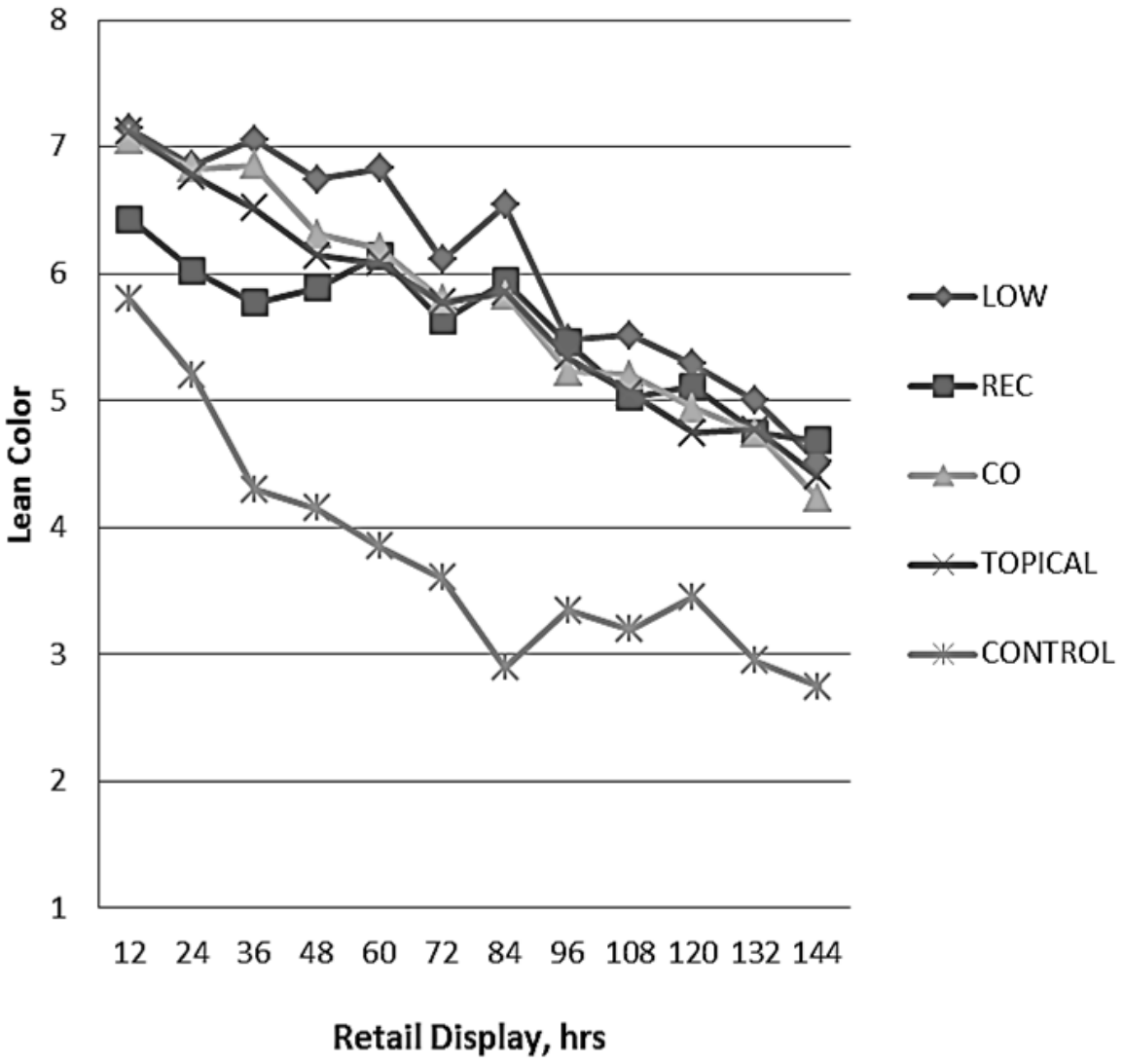


Figure 3.2 Subjective percent discoloration evaluation of various moisture enhancement treatments of ribeye steak displayed over time. LOW = 60% injection of recommended level, REC = recommended injection level, CO = recommended level with .4% carbon monoxide incorparated into the solution, TOPICAL = no injection only topical overspray of recommended solution, CONTROL = salt and phosphate enhancement solution. Percent discoloration scale:1 = none (0%); 2 = 1% to 19%; 3 = 20% to 39%; 4 = 40% to 59%; 5 = 60% to 79%; 6 = 80 to 99%; 7 = total (100%), (n = 7 observations/mean).

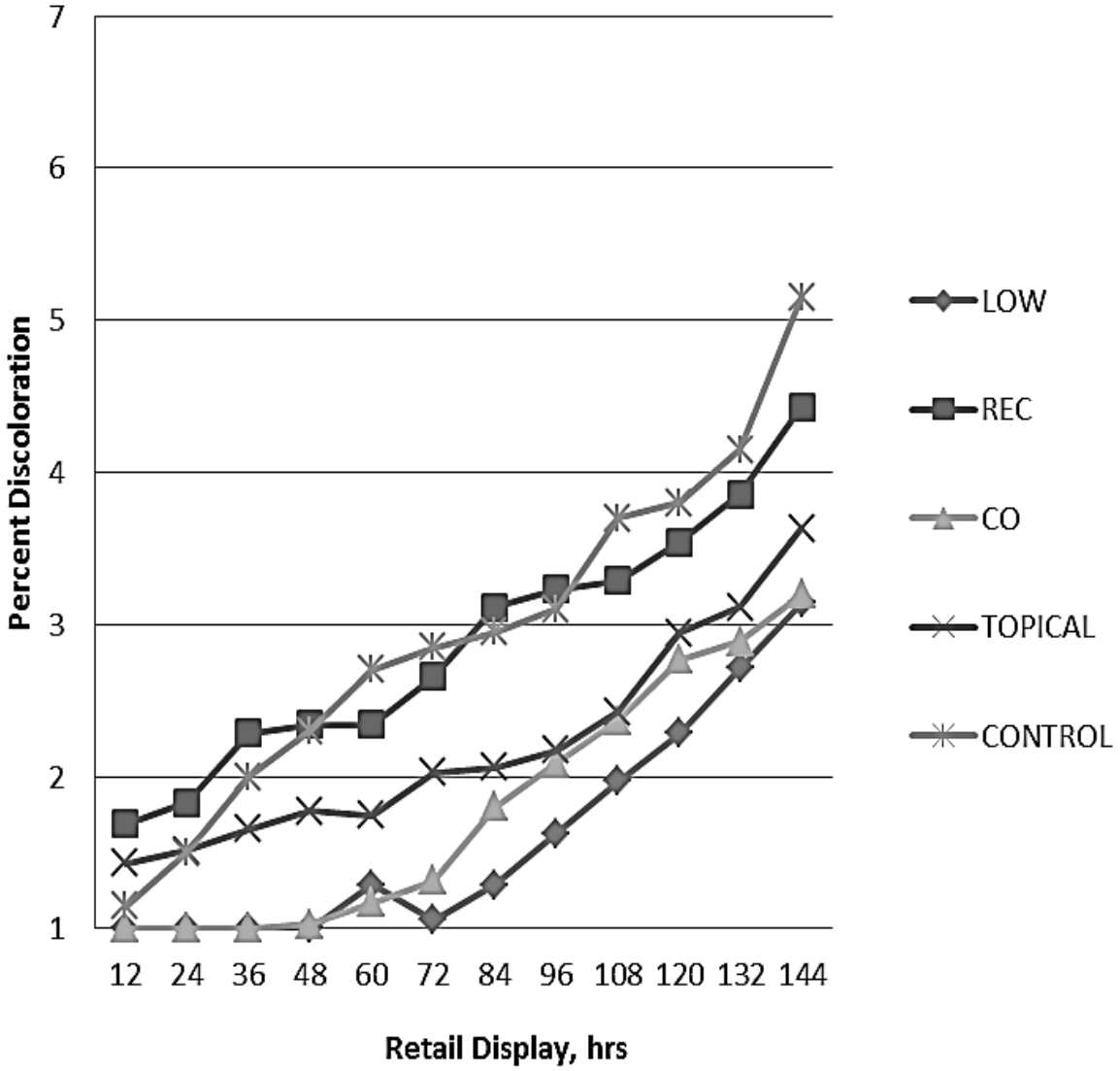


Figure 3.3 Subjective overall appearance evaluation of various moisture enhancement treatments of ribeye steaks displayed over time. LOW = 60% injection of recommended level, REC = recommended injection level, CO = recommended level with .4% carbon monoxide incorparated into the solution, TOPICAL = no injection only topical overspray of recommended solution, CONTROL = salt and phosphate enhancement solution. Overall appearance scale: 8 = extremely desirable; 7 = very desirable; 6 = moderately desirable; 5 = slightly desirable; 4 = slightly undesirable; 3 = moderately undesirable; 2 = very undesirable; 1 = extremely undesirable (n = 7 observations/mean)

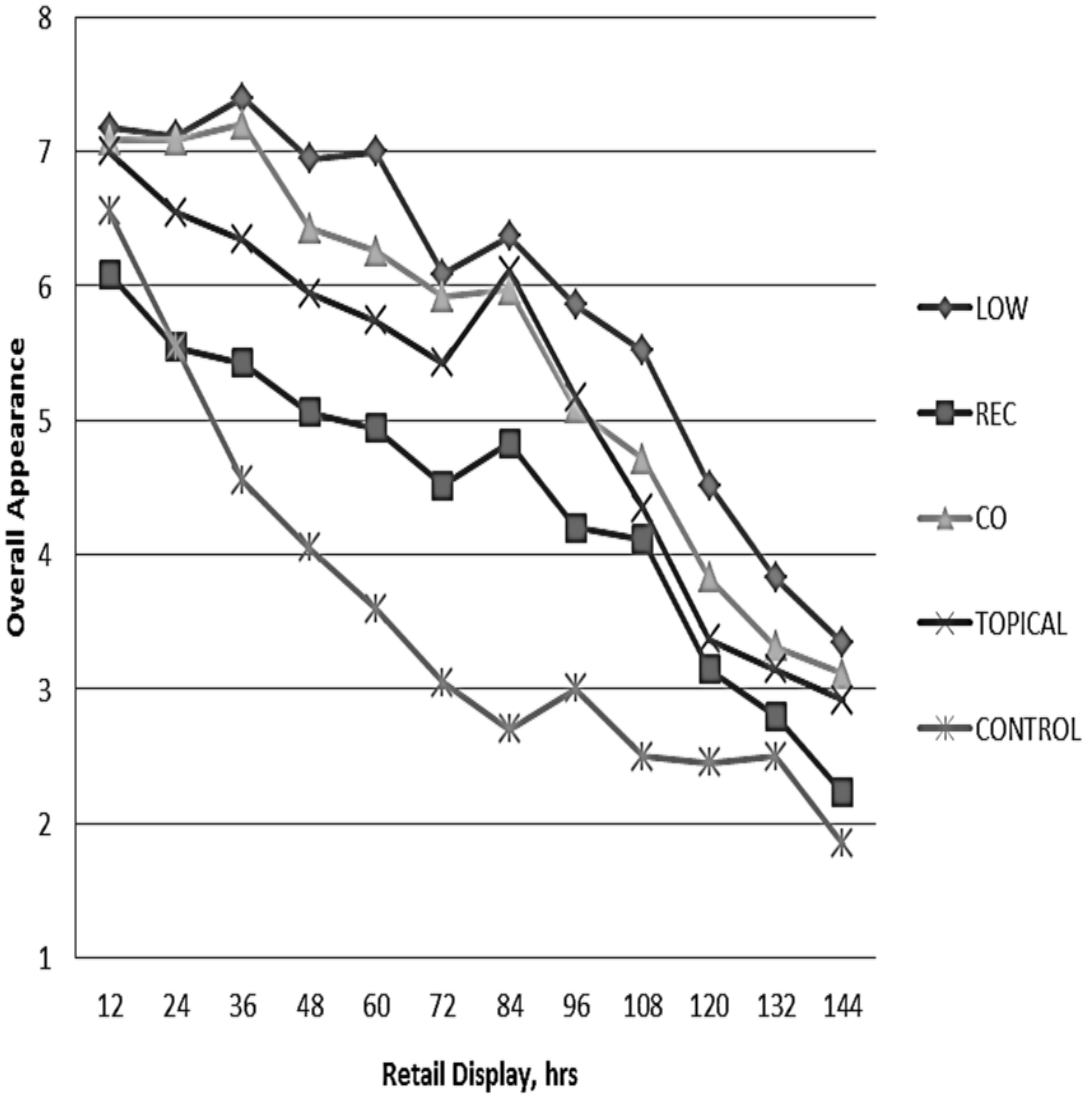


Figure 3.4 Subjective lean color stability evaluation of various moisture enhancement treatments of strip loin steaks displayed over time. LOW = 60% injection of recommended level, REC = recommended injection level, CO = recommended level with .4% carbon monoxide incorparated into the solution, TOPICAL = no injection only topical overspray of recommended solution, CONTROL = salt and phosphate enhancement solution. Lean color scale: 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, (n = 7 observations/mean).

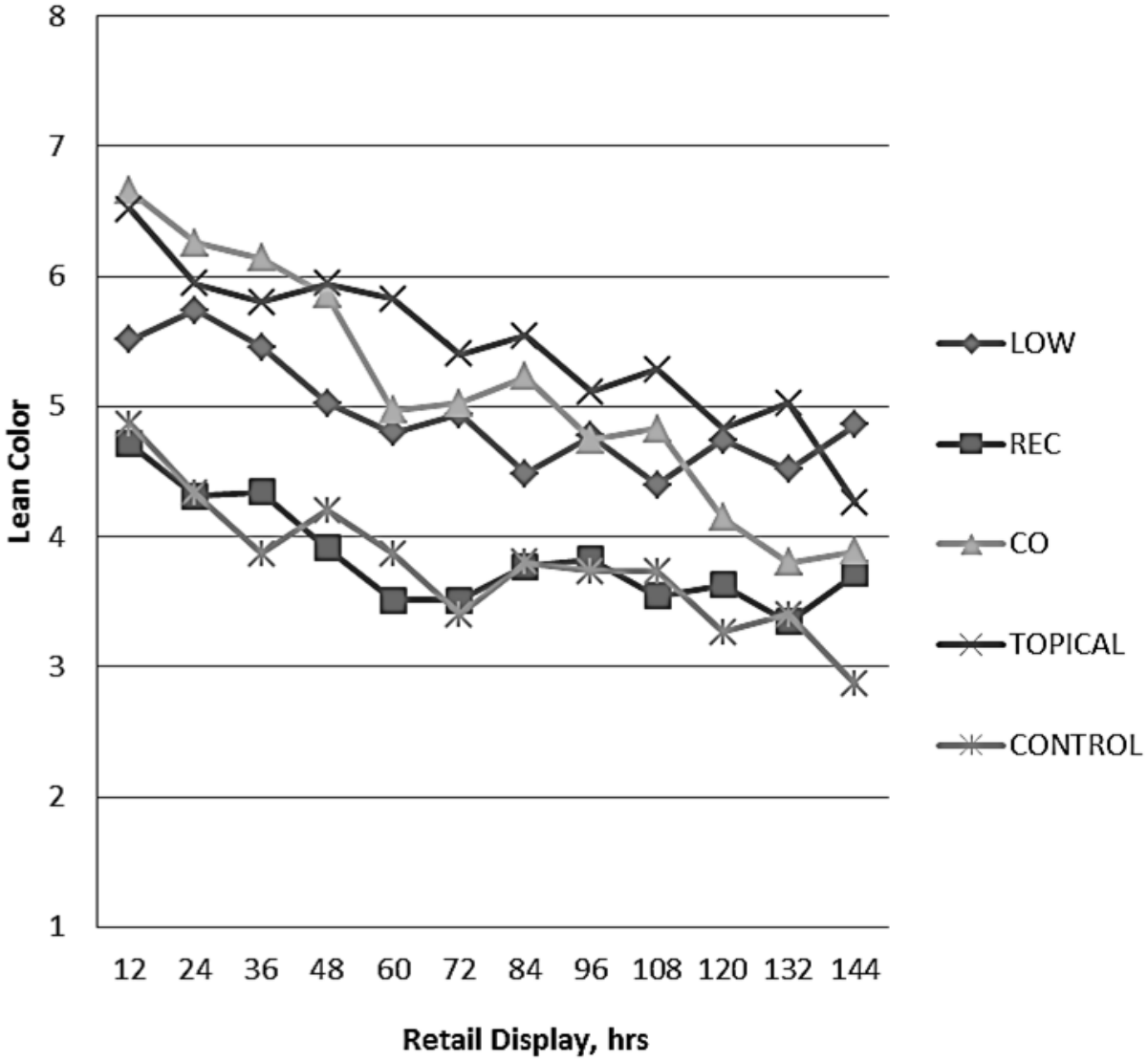


Figure 3.5 Subjective percent discoloration evaluation of various moisture enhancement treatments of strip loin steak displayed over time. LOW = 60% injection of recommended level, REC = recommended injection level, CO = recommended level with .4% carbon monoxide incorparated into the solution, TOPICAL = no injection only topical overspray of recommended solution, CONTROL = salt and phosphate enhancement solution. Percent discoloration scale:1 = none (0%); 2 = 1% to 19%; 3 = 20% to 39%; 4 = 40% to 59%; 5 = 60% to 79%; 6 = 80 to 99%; 7 = total (100%), (n = 7 observations/mean).

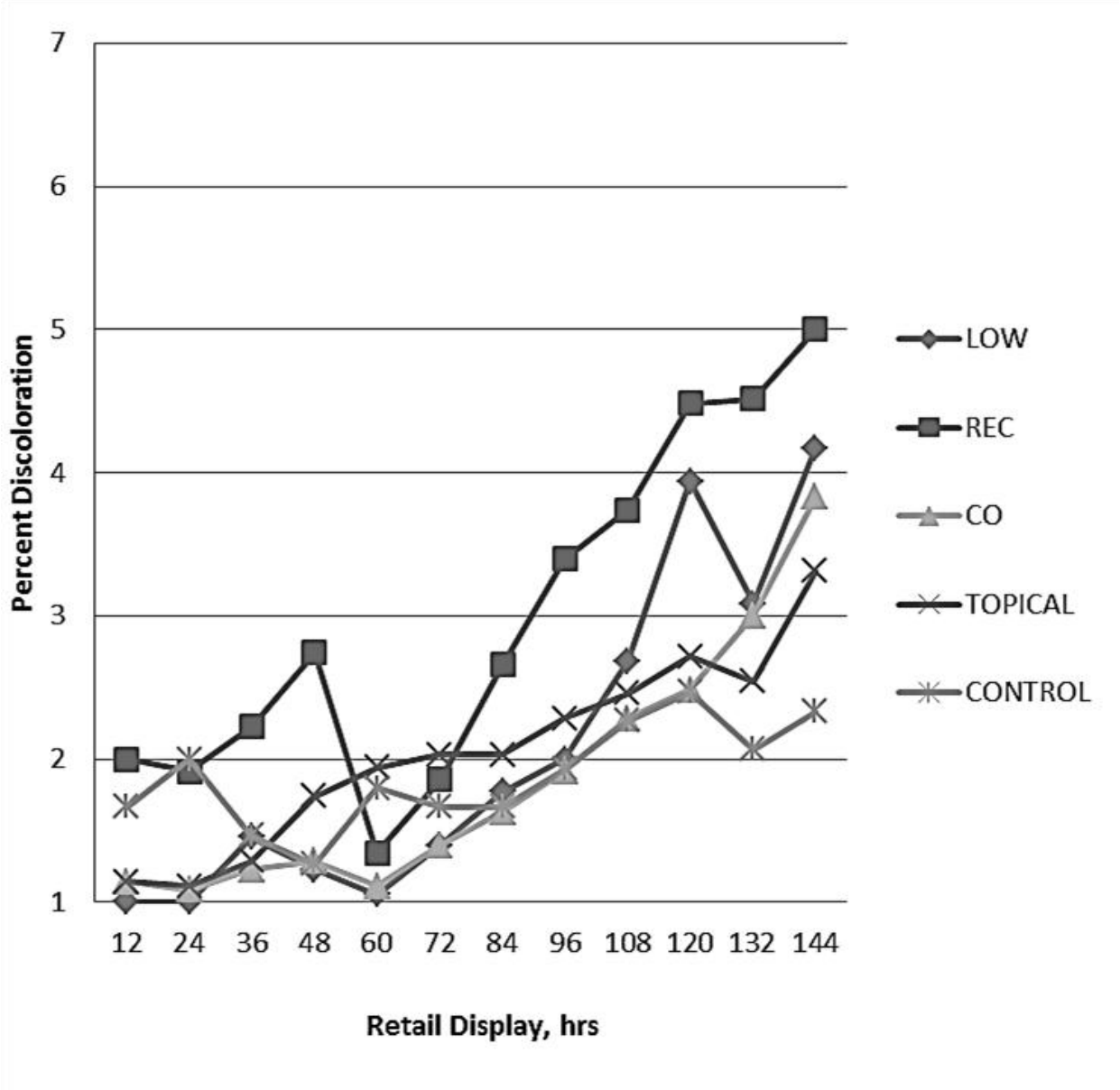


Figure 3.6 Subjective overall appearance evaluation of various moisture enhancement treatments of strip loin steaks displayed over time. LOW = 60% injection of recommended level, REC = recommended injection level, CO = recommended level with .4% carbon monoxide incorparated into the solution, TOPICAL = no injection only topical overspray of recommended solution, CONTROL = salt and phosphate enhancement solution. Overall appearance scale: 8 = extremely desirable; 7 = very desirable; 6 = moderately desirable; 5 = slightly desirable; 4 = slightly undesirable; 3 = moderately undesirable; 2 = very undesirable; 1 = extremely undesirable (n = 7 observations/mean)

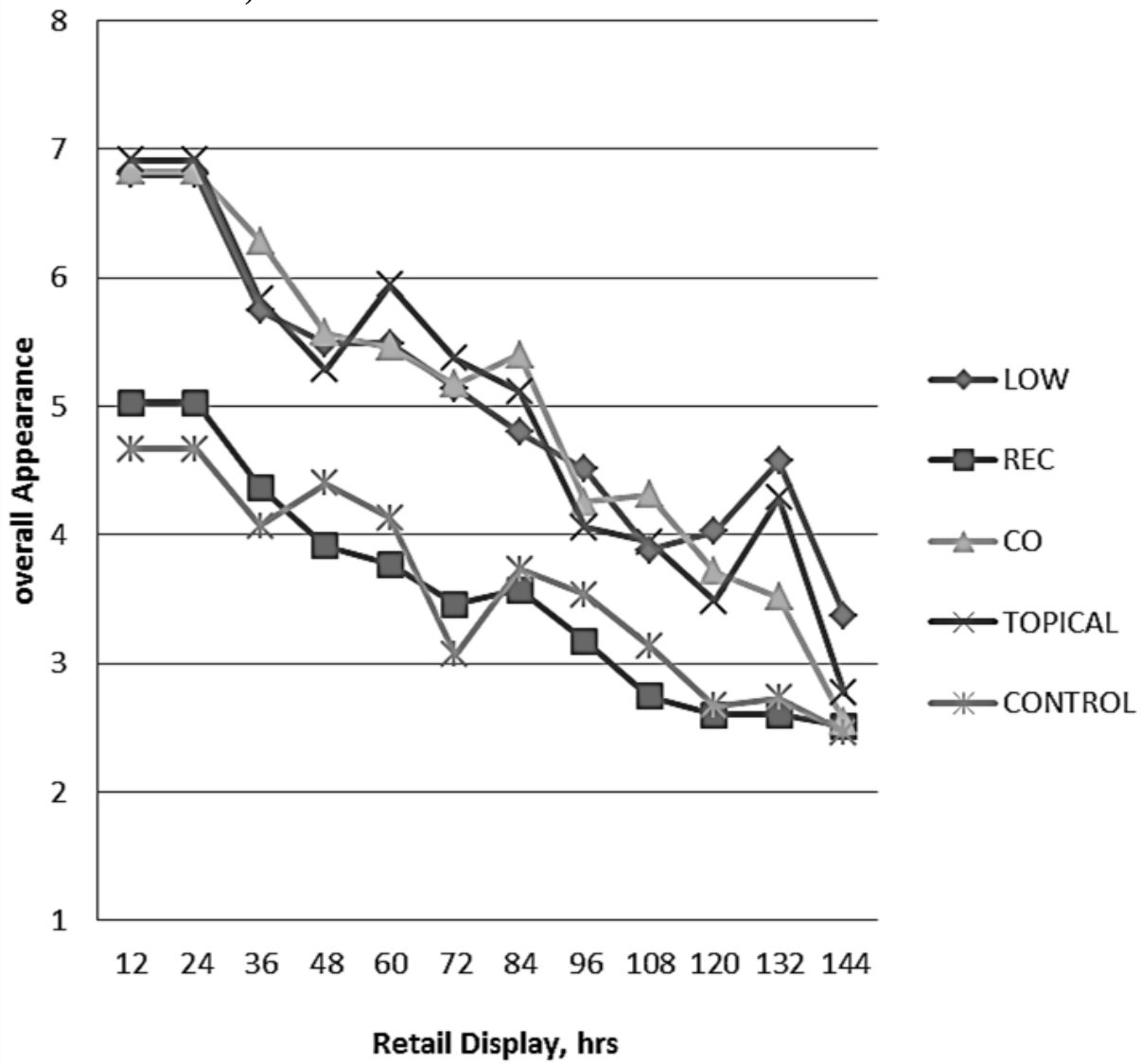


Figure 3.7. Subjective lean color stability evaluation of various moisture enhancement treatments of chuck steaks displayed over time. LOW = 60% injection of recommended level, REC = recommended injection level, CO = recommended level with .4% carbon monoxide incorparated into the solution, TOPICAL = no injection only topical overspray of recommended solution, CONTROL = salt and phosphate enhancement solution. Lean color scale: 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, (n = 7 observations/mean).

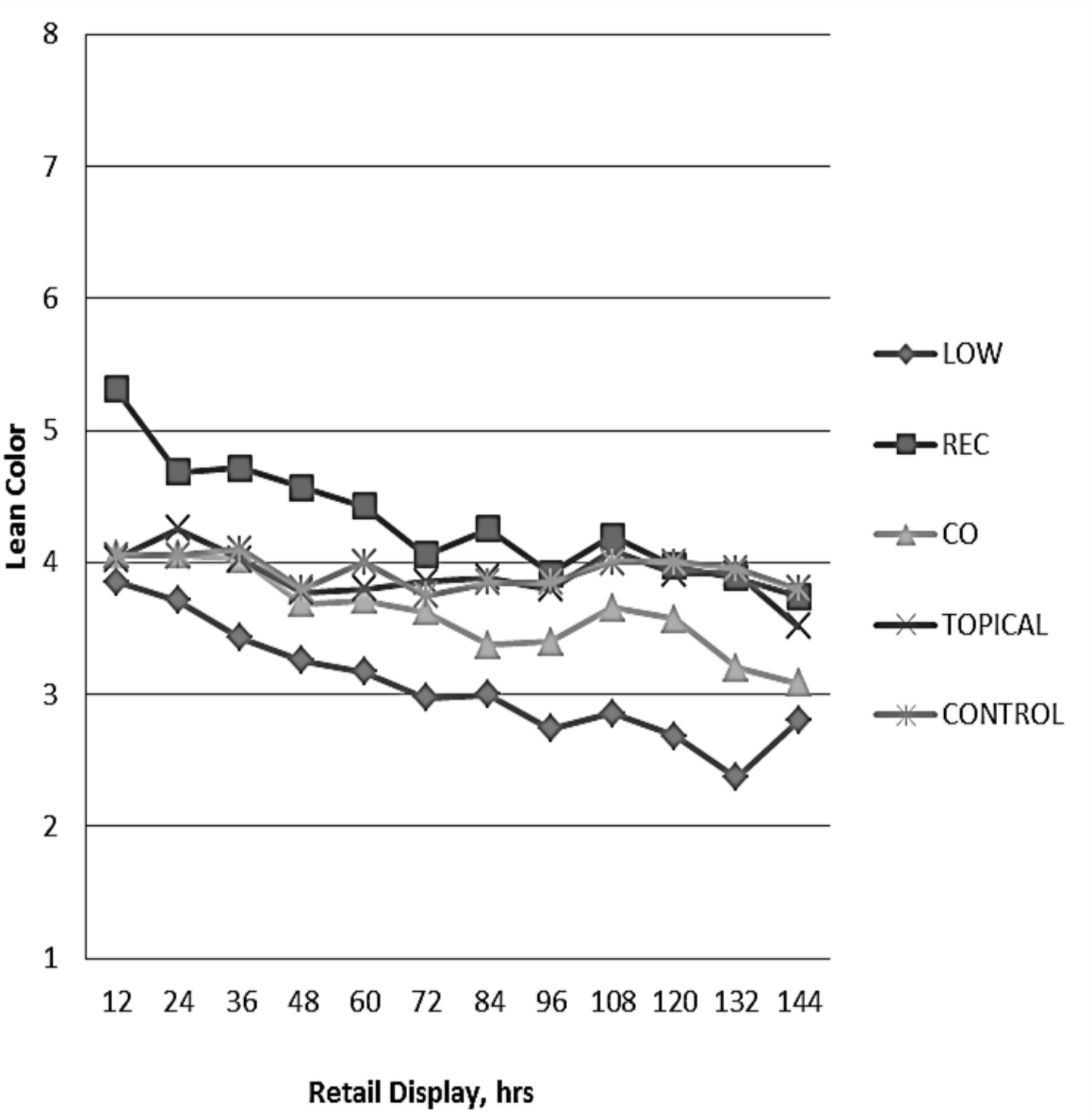


Figure 3.8. Subjective percent discoloration evaluation of various moisture enhancement treatments of chuck steak displayed over time. LOW = 60% injection of recommended level, REC = recommended injection level, CO = recommended level with .4% carbon monoxide incorparated into the solution, TOPICAL = no injection only topical overspray of recommended solution, CONTROL = salt and phosphate enhancement solution. Percent discoloration scale:1 = none (0%); 2 = 1% to 19%; 3 = 20% to 39%; 4 = 40% to 59%; 5 = 60% to 79%; 6 = 80 to 99%; 7 = total (100%), (n = 7 observations/mean).

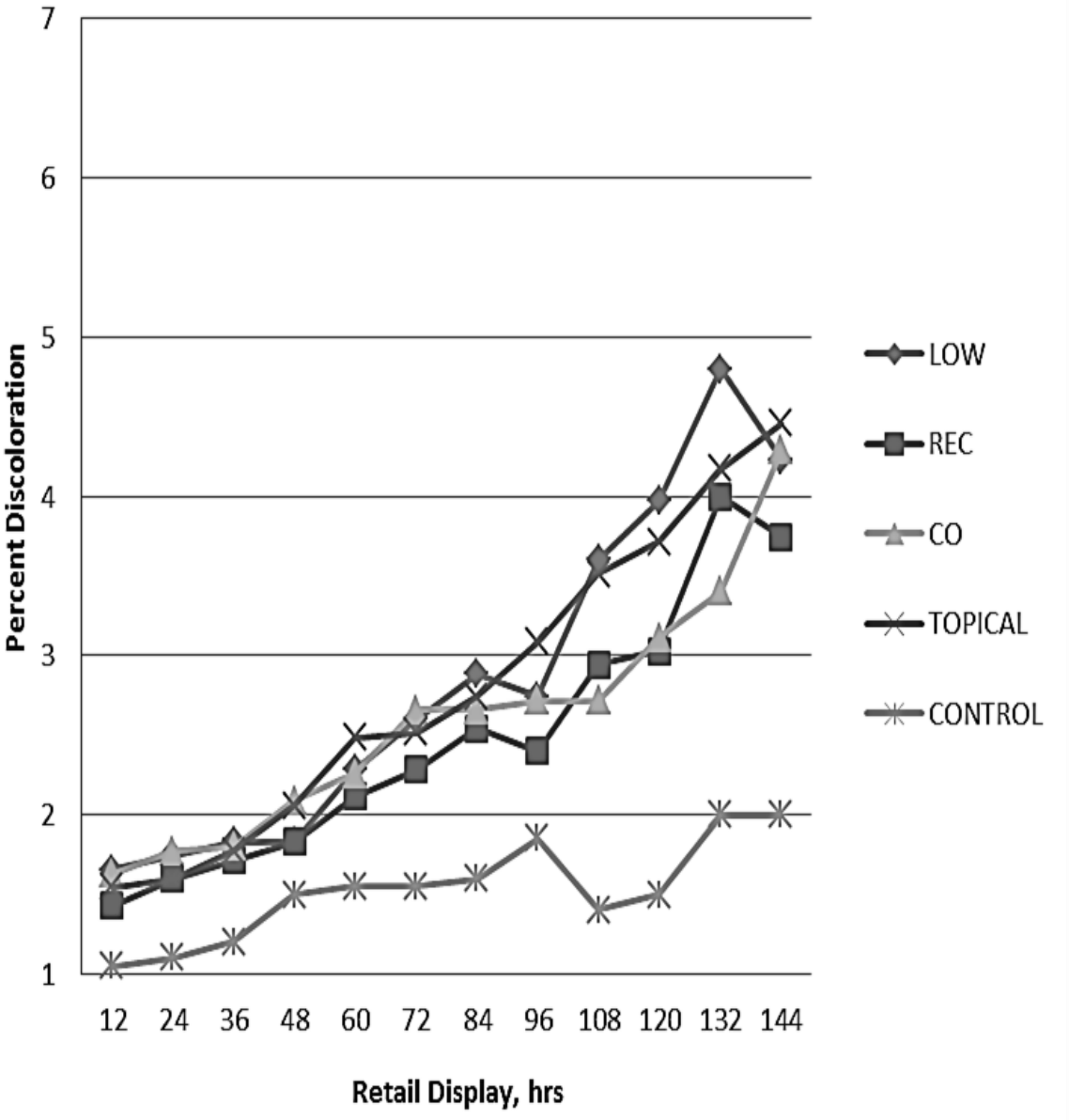


Figure 3.9. Subjective overall appearance evaluation of various moisture enhancement treatments of chuck steaks displayed over time. LOW = 60% injection of recommended level, REC = recommended injection level, CO = recommended level with .4% carbon monoxide incorparated into the solution, TOPICAL = no injection only topical overspray of recommended solution, CONTROL = salt and phosphate enhancement solution. Overall appearance scale: 8 = extremely desirable; 7 = very desirable; 6 = moderately desirable; 5 = slightly desirable; 4 = slightly undesirable; 3 = moderately undesirable; 2 = very undesirable; 1 = extremely undesirable (n = 7 observations/mean)

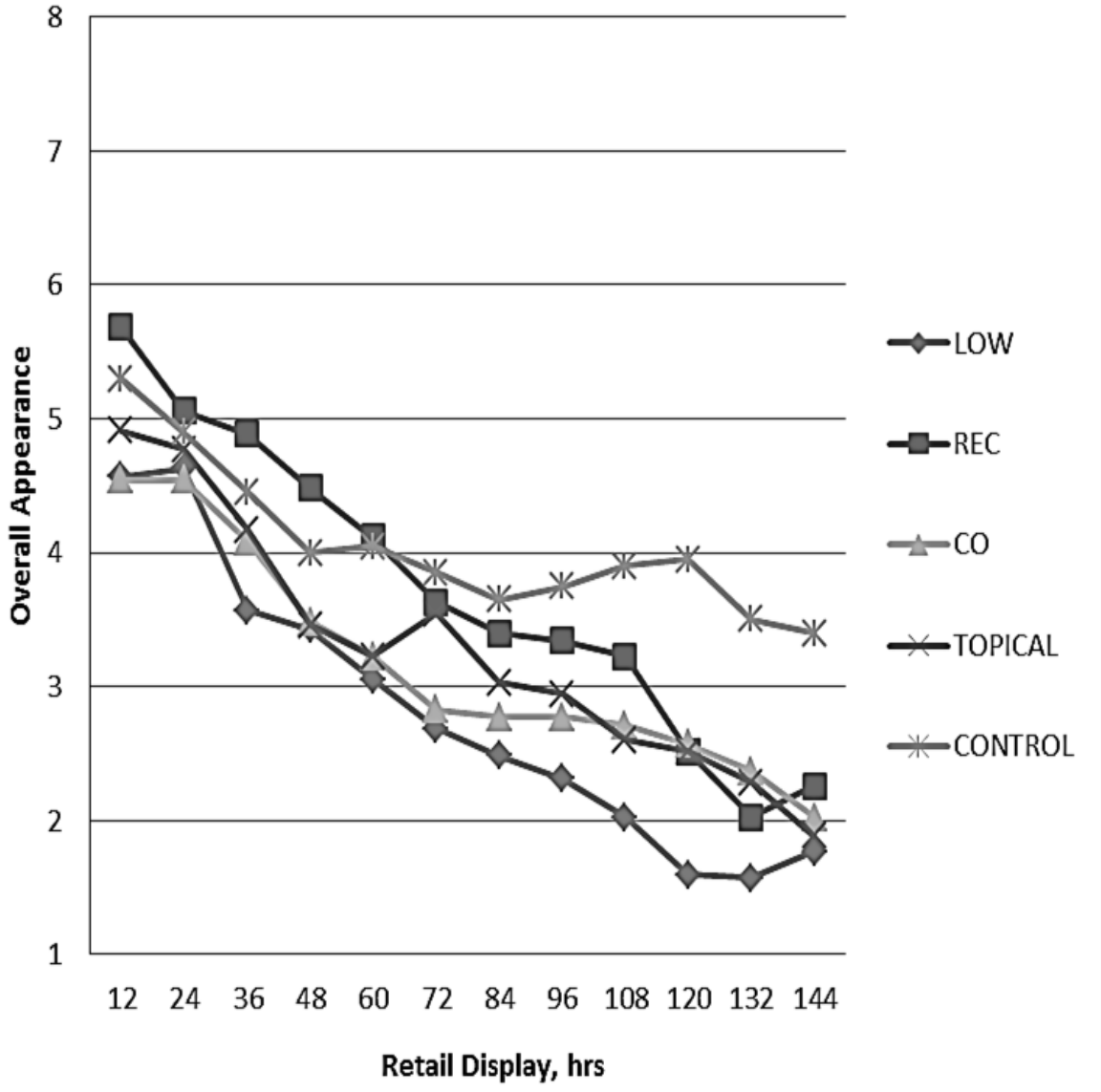


Figure 3.10. Subjective lean color stability evaluation of various moisture enhancement treatments of chuck roast displayed over time. LOW = 60% injection of recommended level, REC = recommended injection level, CO = recommended level with .4% carbon monoxide incorparated into the solution, TOPICAL = no injection only topical overspray of recommended solution, CONTROL = salt and phosphate enhancement solution. Lean color scale: 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, (n = 7 observations/mean).

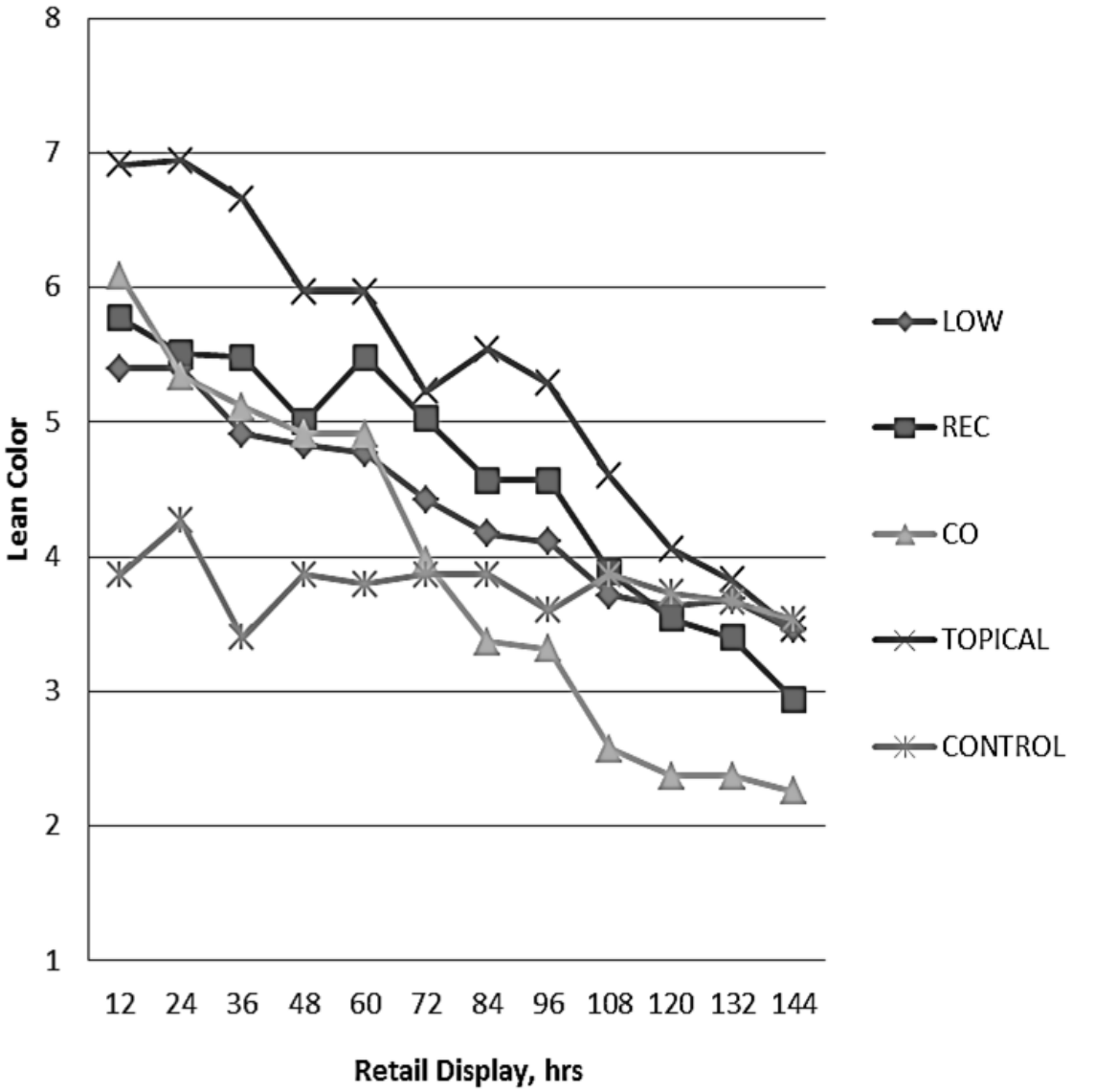


Figure 3.11. Subjective percent discoloration evaluation of various moisture enhancement treatments of chuck roast displayed over time. LOW = 60% injection of recommended level, REC = recommended injection level, CO = recommended level with .4% carbon monoxide incorparated into the solution, TOPICAL = no injection only topical overspray of recommended solution, CONTROL = salt and phosphate enhancement solution. Percent discoloration scale:1 = none (0%); 2 = 1% to 19%; 3 = 20% to 39%; 4 = 40% to 59%; 5 = 60% to 79%; 6 = 80 to 99%; 7 = total (100%), (n = 7 observations/mean).

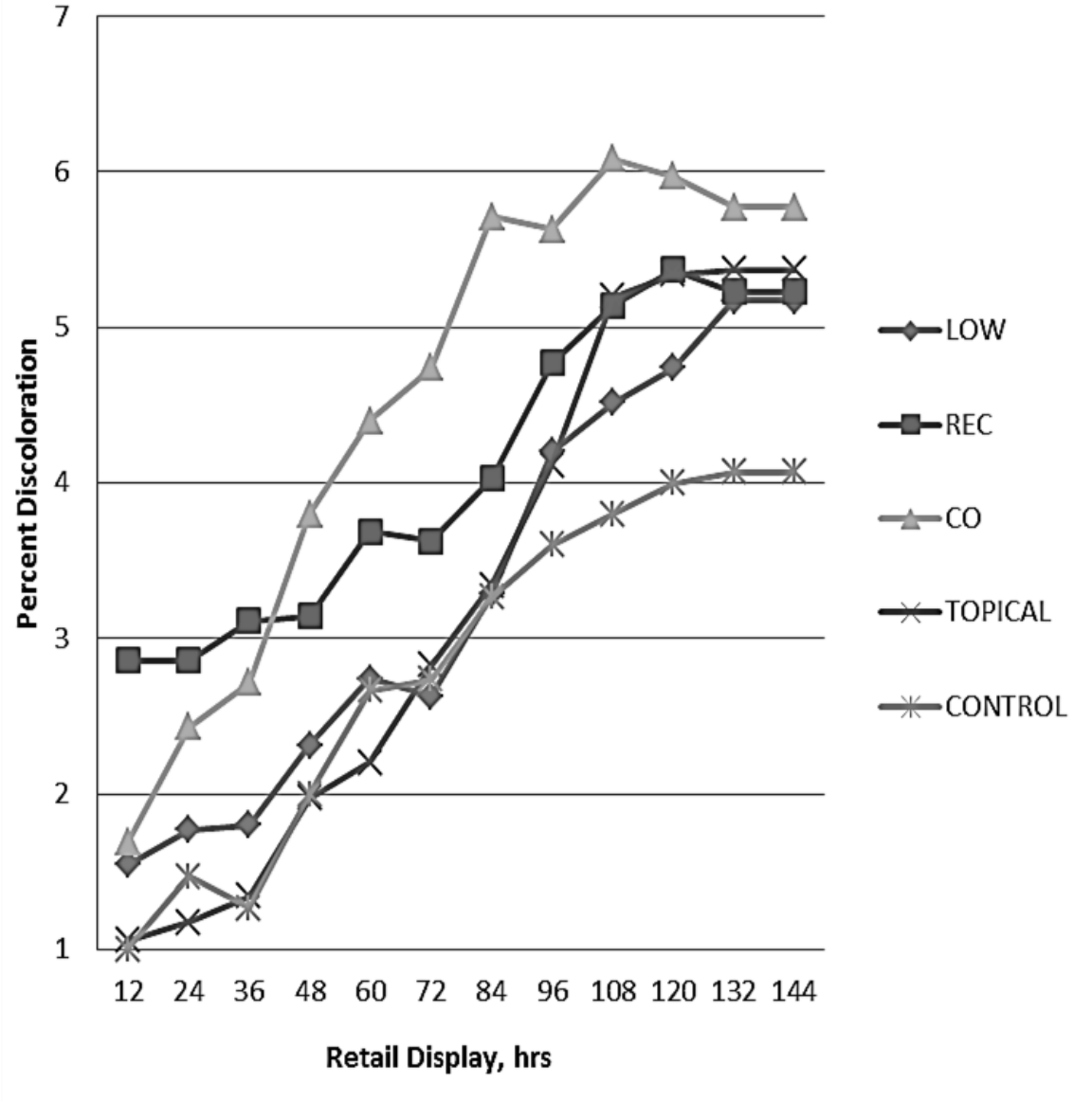


Figure .3.12. Subjective overall appearance evaluation of various moisture enhancement treatments of chuck roast displayed over time. LOW = 60% injection of recommended level, REC = recommended injection level, CO = recommended level with .4% carbon monoxide incorparated into the solution, TOPICAL = no injection only topical overspray of recommended solution, CONTROL = salt and phosphate enhancement solution. Overall appearance scale: 8 = extremely desirable; 7 = very desirable; 6 = moderately desirable; 5 = slightly desirable; 4 = slightly undesirable; 3 = moderately undesirable; 2 = very undesirable; 1 = extremely undesirable (n = 7 observations/mean).

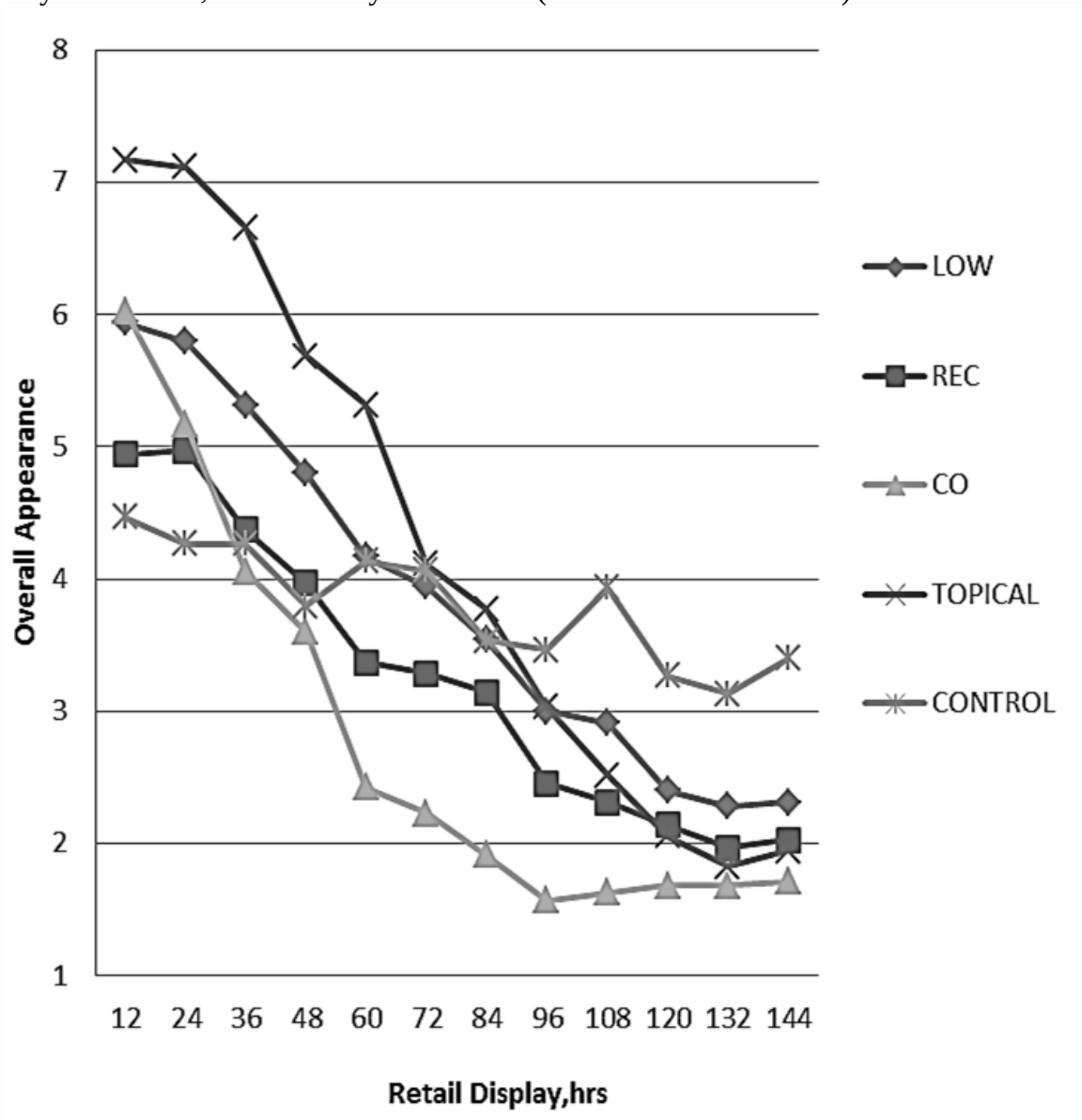


Figure 3.13. Subjective lean color stability evaluation of various moisture enhancement treatments of eye of round steak displayed over time. LOW = 60% injection of recommended level, REC = recommended injection level, CO = recommended level with .4% carbon monoxide incorparated into the solution, TOPICAL = no injection only topical overspray of recommended solution, CONTROL = salt and phosphate enhancement solution. Lean color scale: 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, (n = 7 observations/mean).

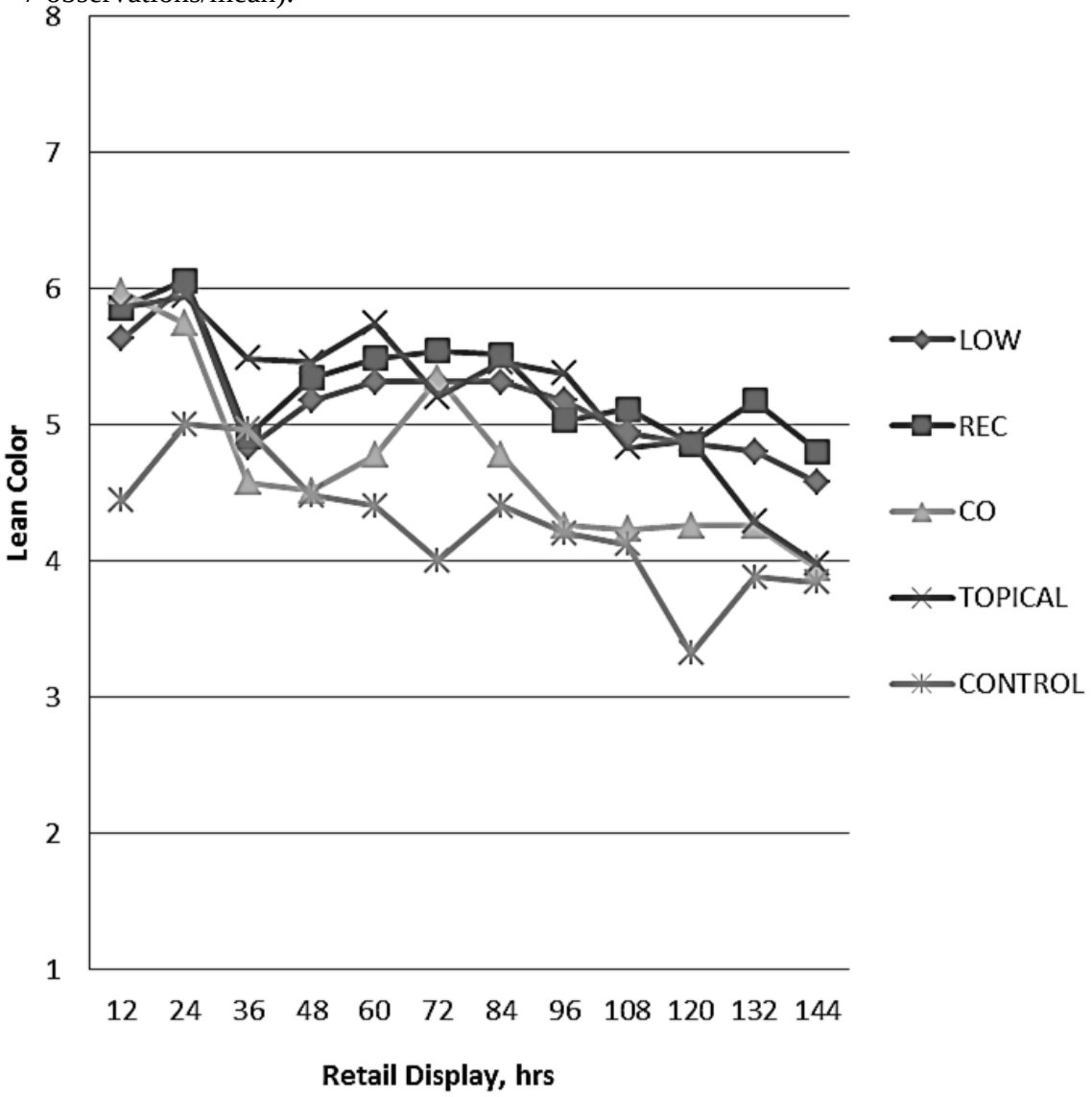


Figure 3.14. Subjective percent discoloration evaluation of various moisture enhancement treatments of eye of round steak displayed over time. LOW = 60% injection of recommended level, REC = recommended injection level, CO = recommended level with .4% carbon monoxide incorparated into the solution, TOPICAL = no injection only topical overspray of recommended solution, CONTROL = salt and phosphate enhancement solution. Percent discoloration scale:1 = none (0%); 2 = 1% to 19%; 3 = 20% to 39%; 4 = 40% to 59%; 5 = 60% to 79%; 6 = 80 to 99%; 7 = total (100%), (n = 7 observations/mean).

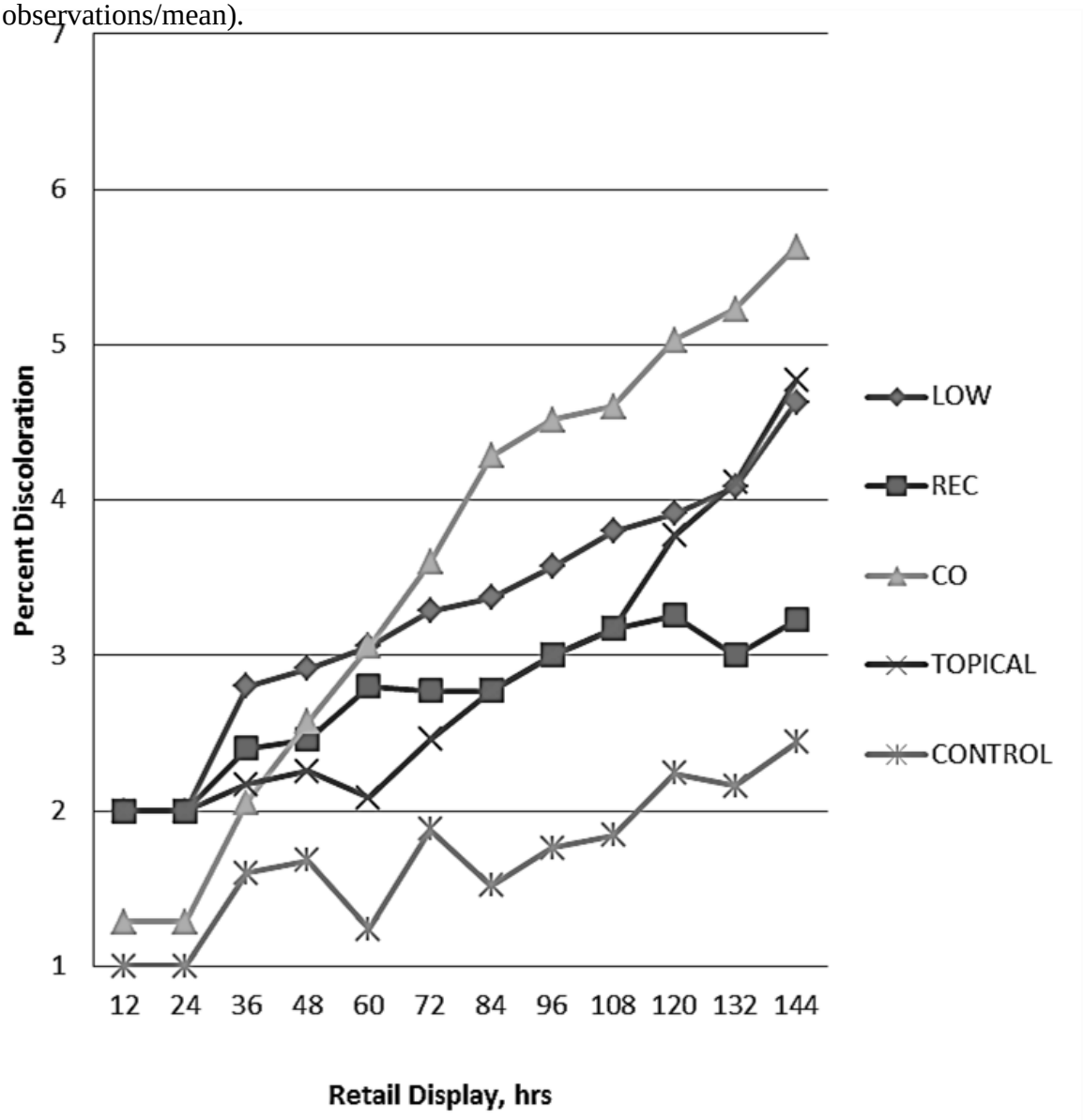


Figure 3.15. Subjective overall appearance evaluation of various moisture enhancement treatments of eye of round steak displayed over time. LOW = 60% injection of recommended level, REC = recommended injection level, CO = recommended level with .4% carbon monoxide incorparated into the solution, TOPICAL = no injection only topical overspray of recommended solution, CONTROL = salt and phosphate enhancement solution. Overall appearance scale: 8 = extremely desirable; 7 = very desirable; 6 = moderately desirable; 5 = slightly desirable; 4 = slightly undesirable; 3 = moderately undesirable; 2 = very undesirable; 1 = extremely undesirable (n = 7 observations/mean).

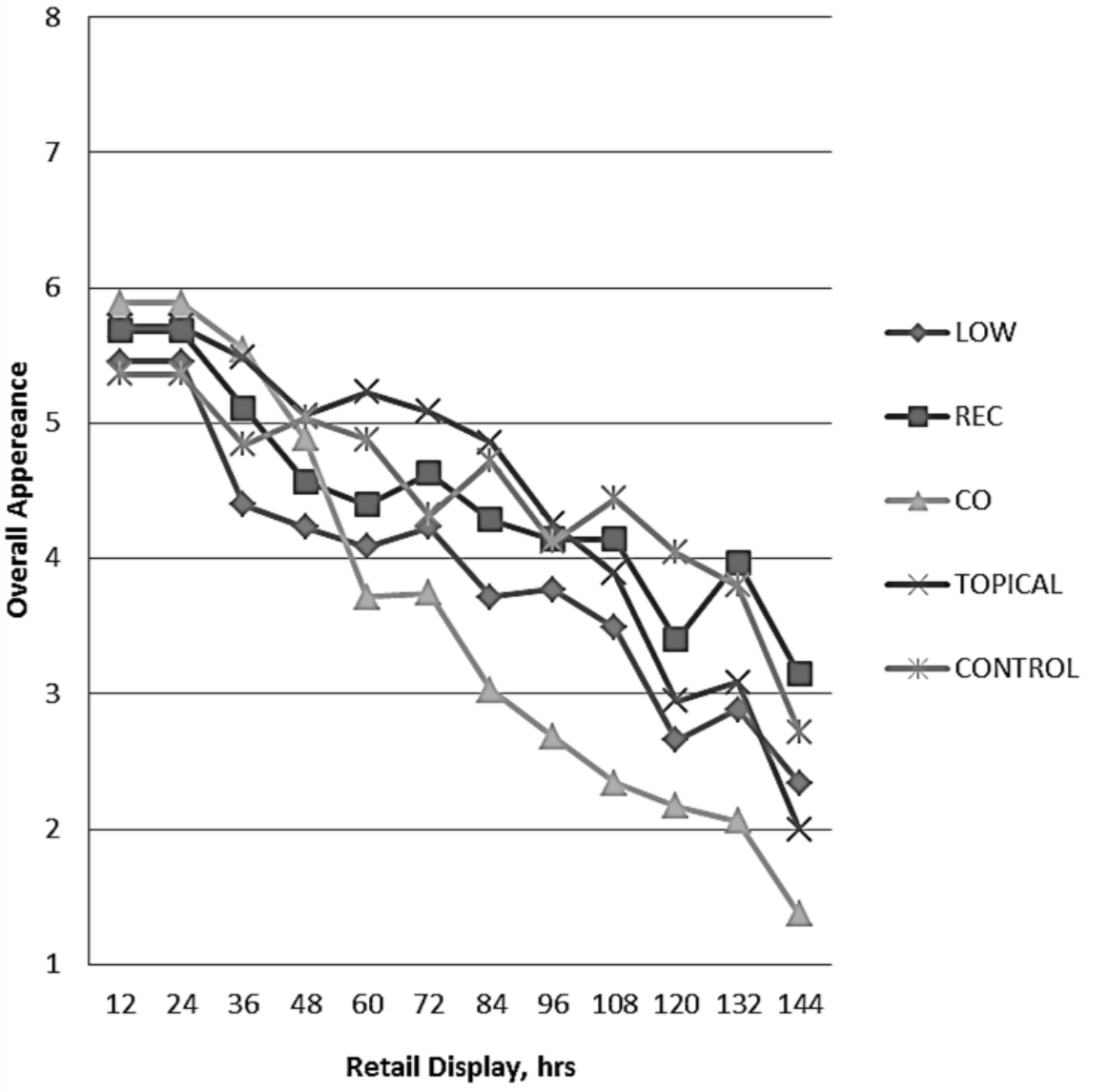


Figure 3.16. Subjective lean color stability evaluation of various moisture enhancement treatments of top sirloin steak displayed over time. LOW = 60% injection of recommended level, REC = recommended injection level, CO = recommended level with .4% carbon monoxide incorparated into the solution, TOPICAL = no injection only topical overspray of recommended solution, CONTROL = salt and phosphate enhancement solution. Lean color scale: 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, (n = 7 observations/mean).

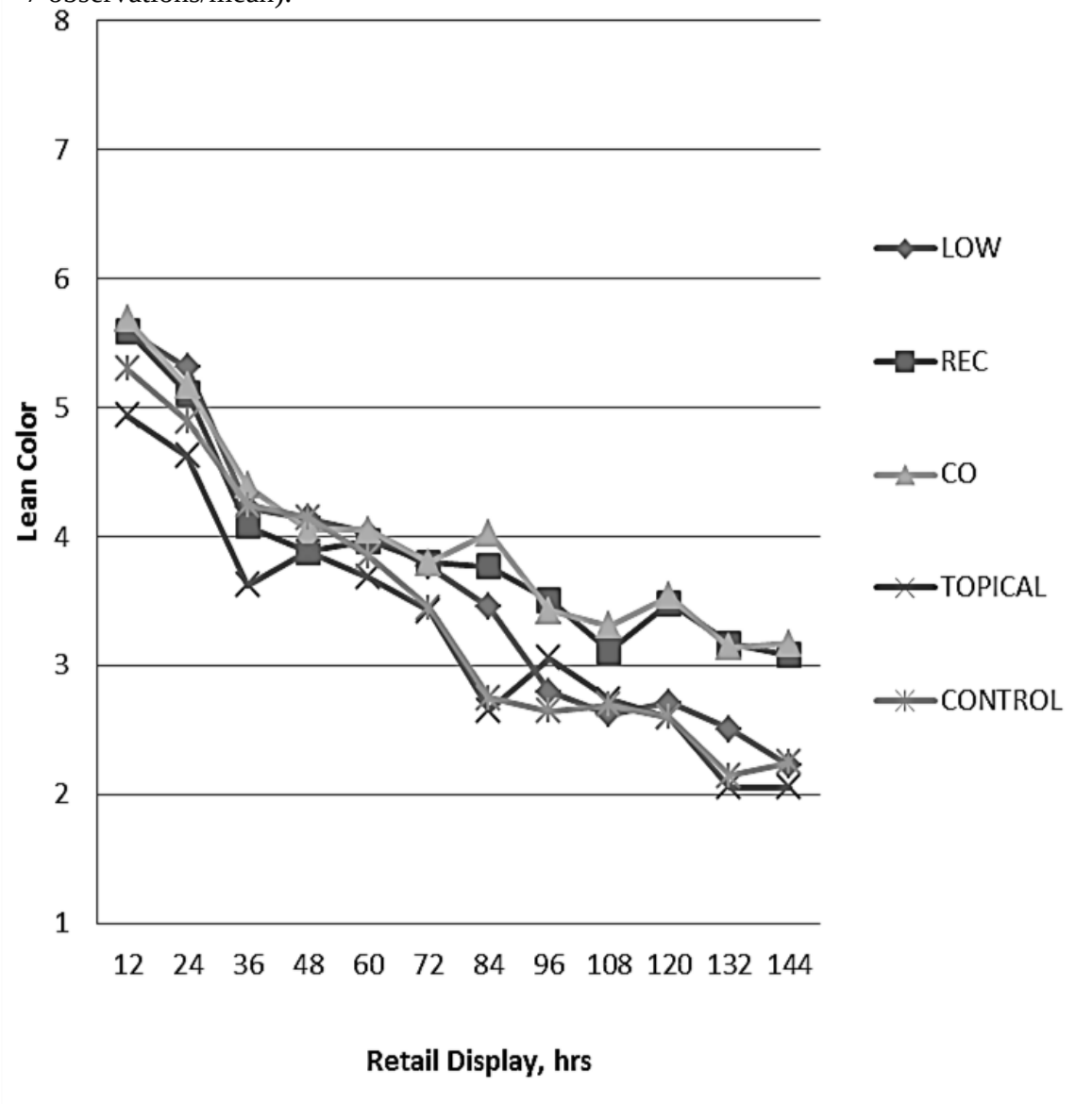


Figure 3.17. Subjective percent discoloration evaluation of various moisture enhancement treatments of top sirloin steak displayed over time. LOW = 60% injection of recommended level, REC = recommended injection level, CO = recommended level with .4% carbon monoxide incorparated into the solution, TOPICAL = no injection only topical overspray of recommended solution, CONTROL = salt and phosphate enhancement solution. Percent discoloration scale:1 = none (0%); 2 = 1% to 19%; 3 = 20% to 39%; 4 = 40% to 59%; 5 = 60% to 79%; 6 = 80 to 99%; 7 = total (100%), (n = 7 observations/mean).

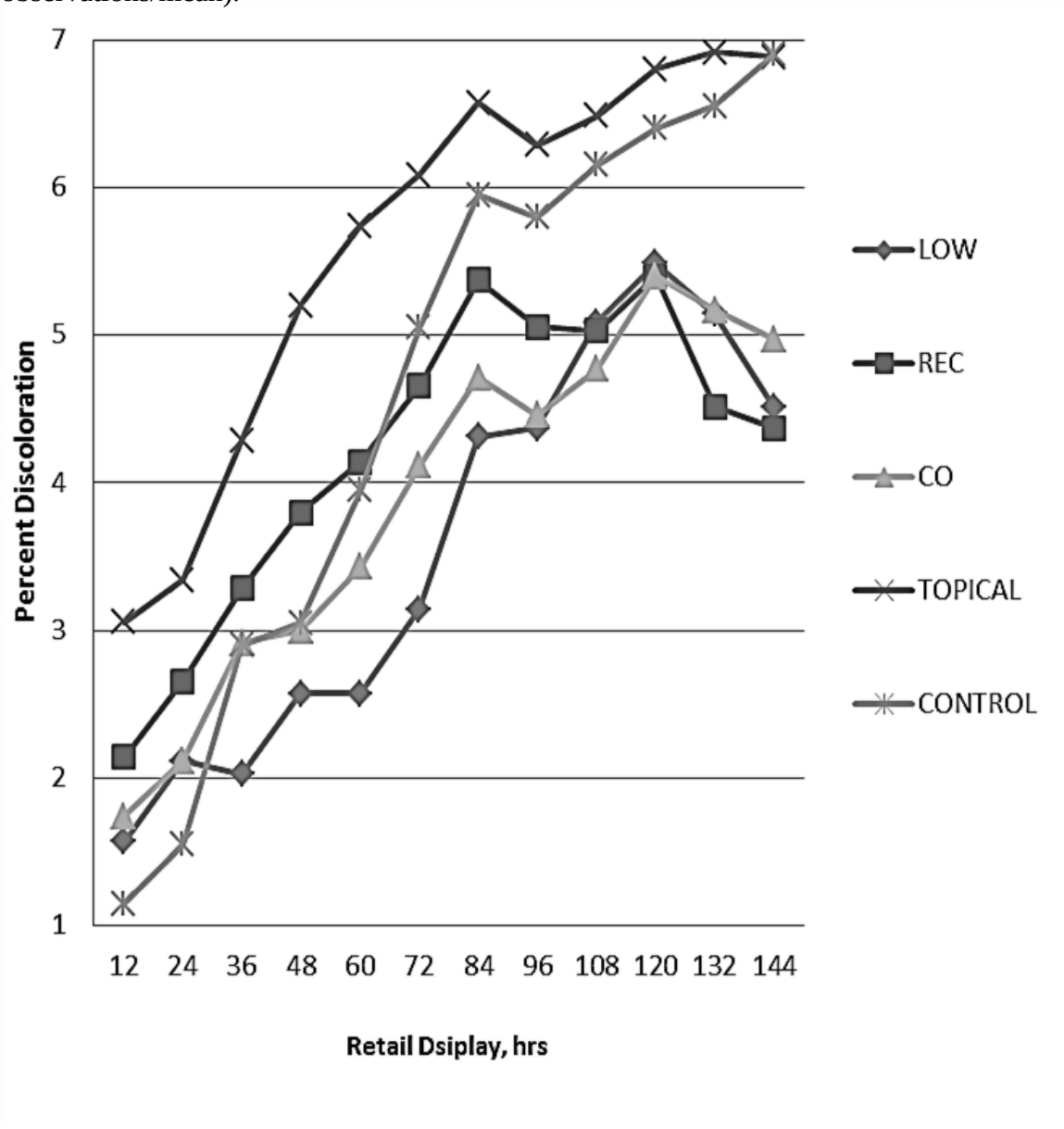


Figure .3.18. Subjective overall appearance evaluation of various moisture enhancement treatments of top sirloin steak displayed over time. LOW = 60% injection of recommended level, REC = recommended injection level, CO = recommended level with .4% carbon monoxide incorparated into the solution, TOPICAL = no injection only topical overspray of recommended solution, CONTROL = salt and phosphate enhancement solution. Overall appearance scale: 8 = extremely desirable; 7 = very desirable; 6 = moderately desirable; 5 = slightly desirable; 4 = slightly undesirable; 3 = moderately undesirable; 2 = very undesirable; 1 = extremely undesirable (n = 7 observations/mean).

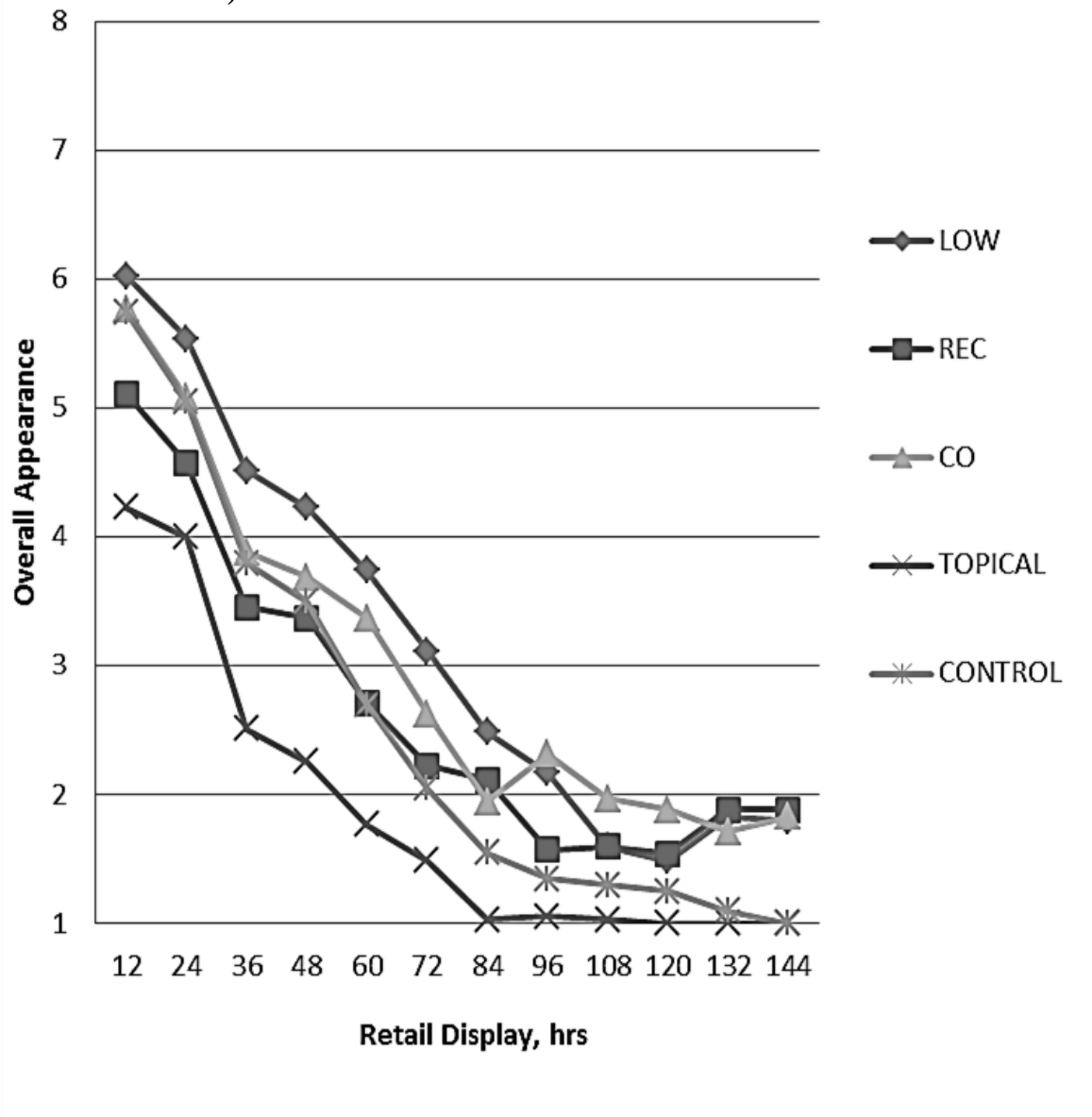


Figure 3.19. Subjective lean color stability evaluation of various moisture enhancement treatments of inside round steak displayed over time. LOW = 60% injection of recommended level, REC = recommended injection level, CO = recommended level with .4% carbon monoxide incorparated into the solution, TOPICAL = no injection only topical overspray of recommended solution, CONTROL = salt and phosphate enhancement solution. Lean color scale: 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, (n = 7 observations/mean).

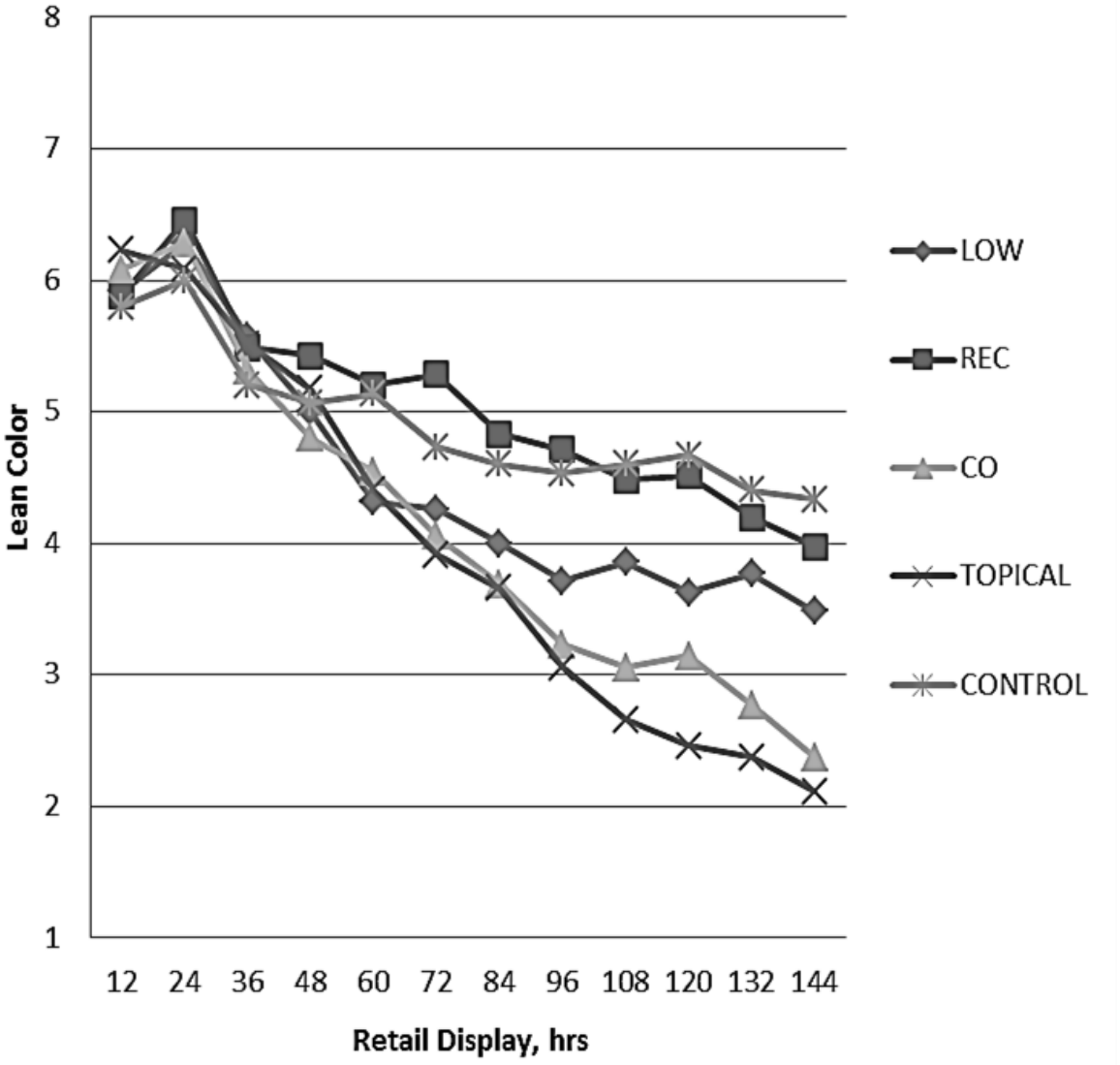


Figure 3.20. Subjective percent discoloration evaluation of various moisture enhancement treatments of inside round steak displayed over time. LOW = 60% injection of recommended level, REC = recommended injection level, CO = recommended level with .4% carbon monoxide incorparated into the solution, TOPICAL = no injection only topical overspray of recommended solution, CONTROL = salt and phosphate enhancement solution. Percent discoloration scale:1 = none (0%); 2 = 1% to 19%; 3 = 20% to 39%; 4 = 40% to 59%; 5 = 60% to 79%; 6 = 80 to 99%; 7 = total (100%), (n = 7 observations/mean)

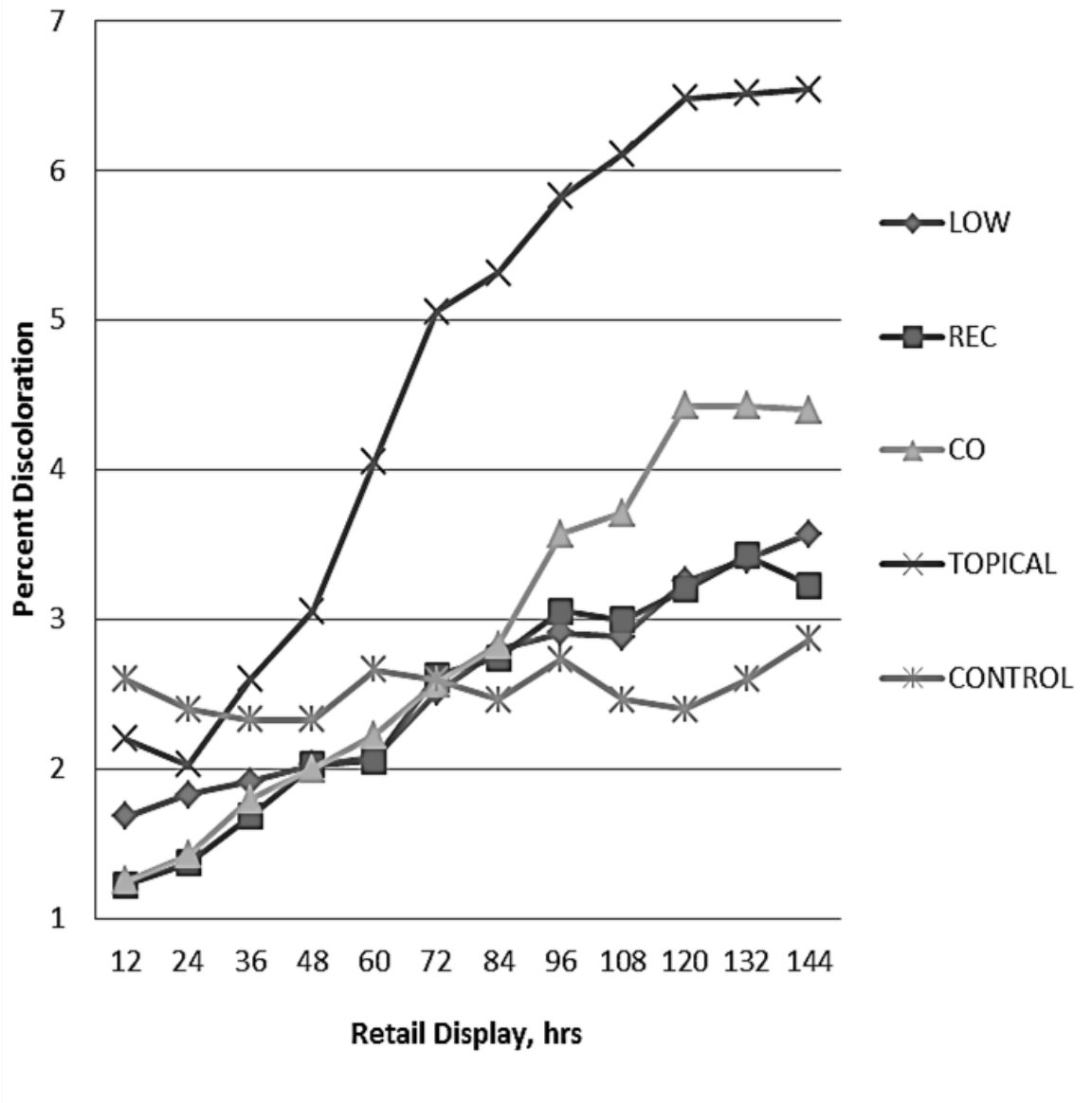


Figure 3.21. Subjective overall appearance evaluation of various moisture enhancement treatments of inside round steak displayed over time. LOW = 60% injection of recommended level, REC = recommended injection level, CO = recommended level with .4% carbon monoxide incorparated into the solution, TOPICAL = no injection only topical overspray of recommended solution, CONTROL = salt and phosphate enhancement solution. Overall appearance scale: 8 = extremely desirable; 7 = very desirable; 6 = moderately desirable; 5 = slightly desirable; 4 = slightly undesirable; 3 = moderately undesirable; 2 = very undesirable; 1 = extremely undesirable (n = 7 observations/mean).

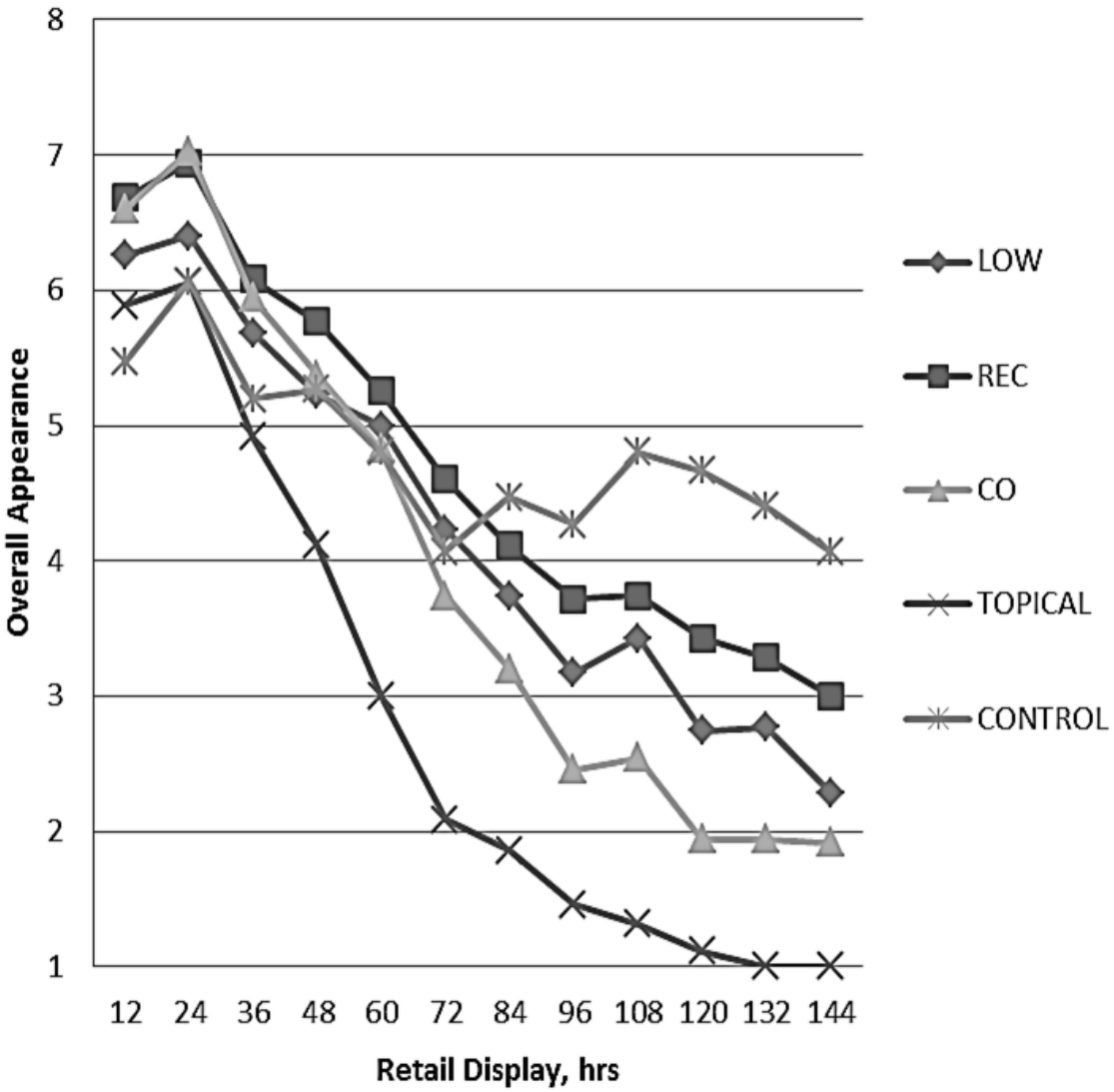


Figure 3.22. Subjective lean color stability evaluation of various moisture enhancement treatments of bottom round roast displayed over time. LOW = 60% injection of recommended level, REC = recommended injection level, CO = recommended level with .4% carbon monoxide incorparated into the solution, TOPICAL = no injection only topical overspray of recommended solution, CONTROL = salt and phosphate enhancement solution. Lean color scale: 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, (n = 7 observations/mean)

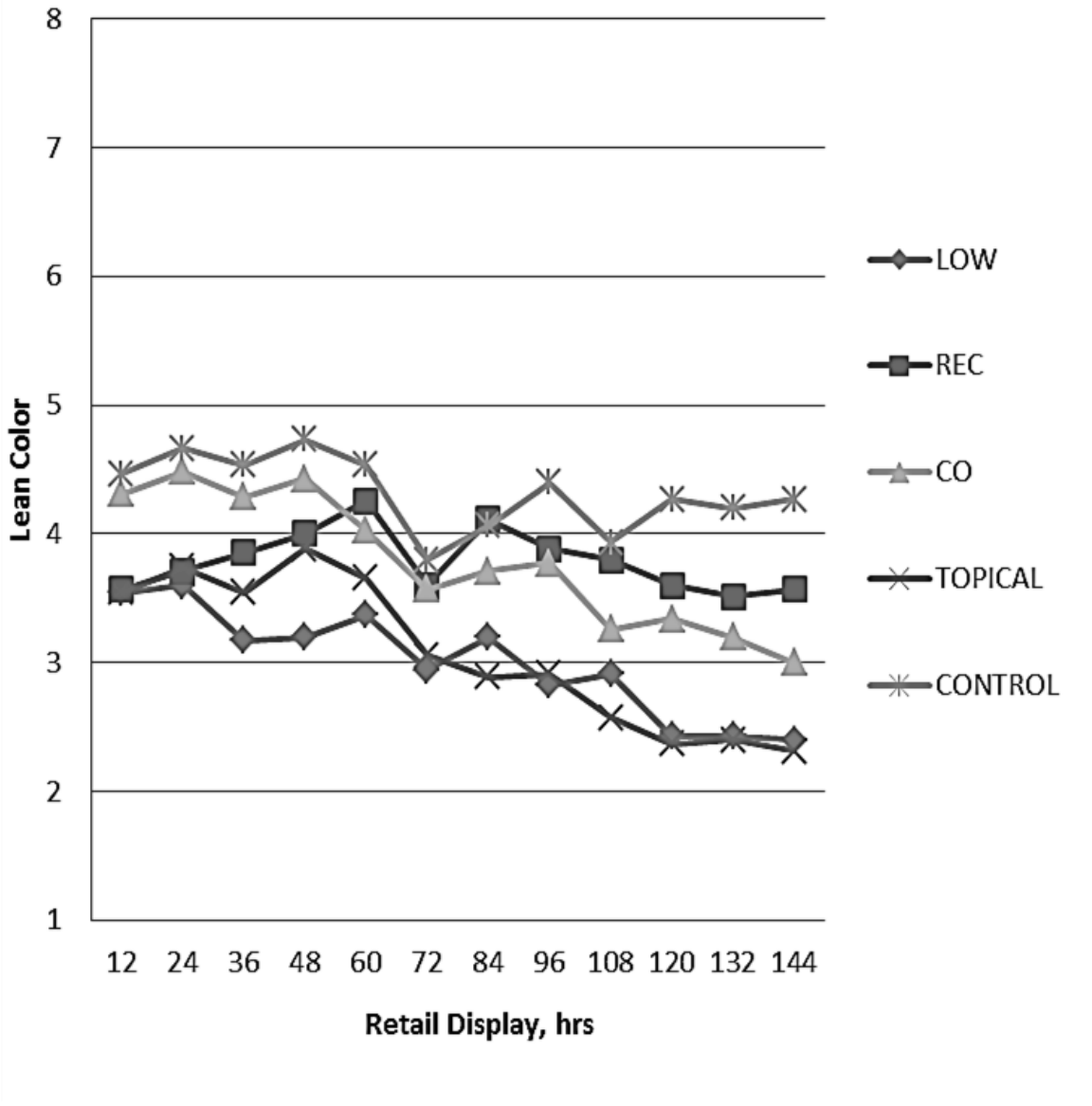


Figure 3.23. Subjective percent discoloration evaluation of various moisture enhancement treatments of bottom round roast displayed over time. LOW = 60% injection of recommended level, REC = recommended injection level, CO = recommended level with .4% carbon monoxide incorparated into the solution, TOPICAL = no injection only topical overspray of recommended solution, CONTROL = salt and phosphate enhancement solution. Percent discoloration scale:1 = none (0%); 2 = 1% to 19%; 3 = 20% to 39%; 4 = 40% to 59%; 5 = 60% to 79%; 6 = 80 to 99%; 7 = total (100%), (n = 7 observations/mean)

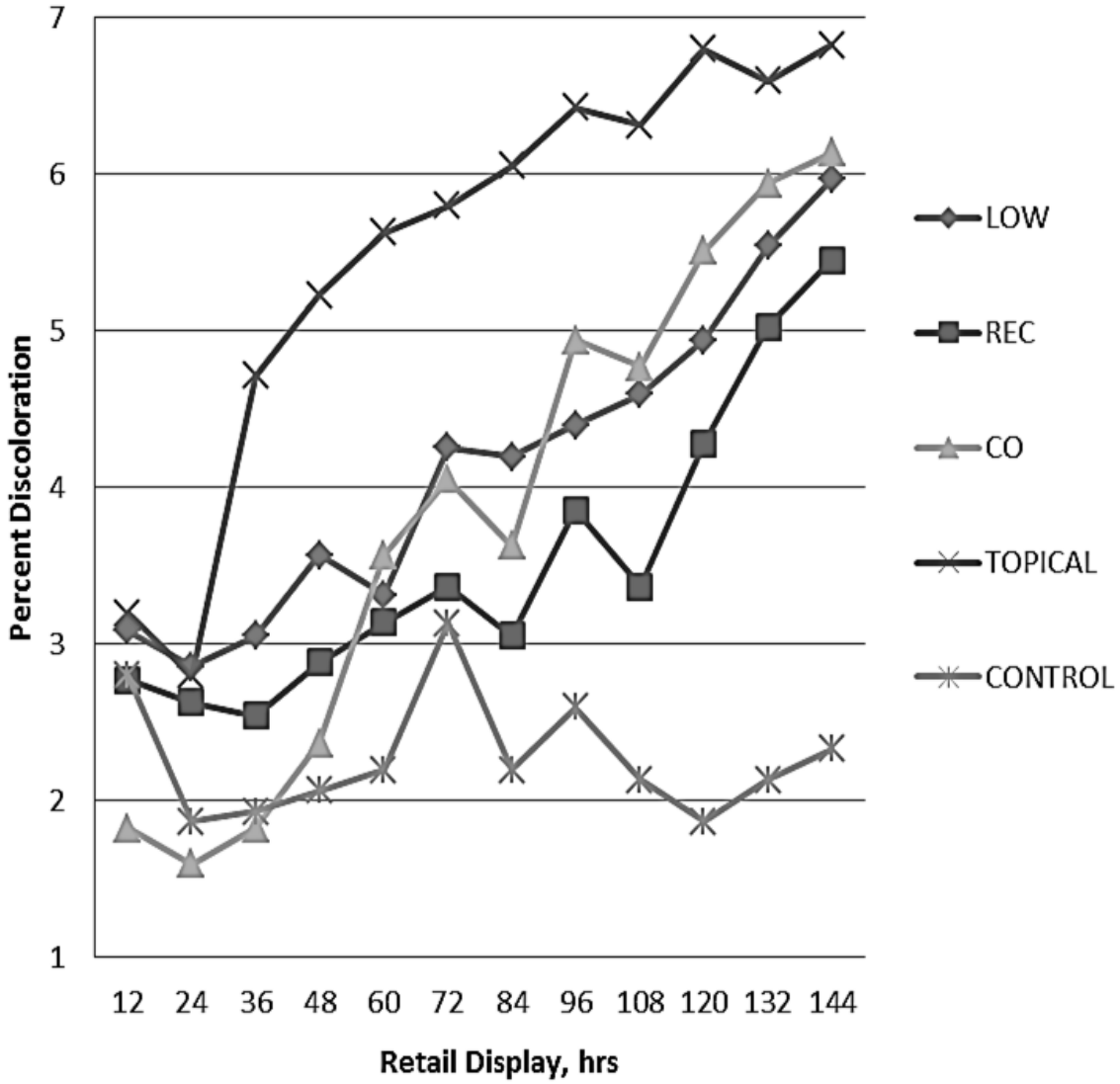
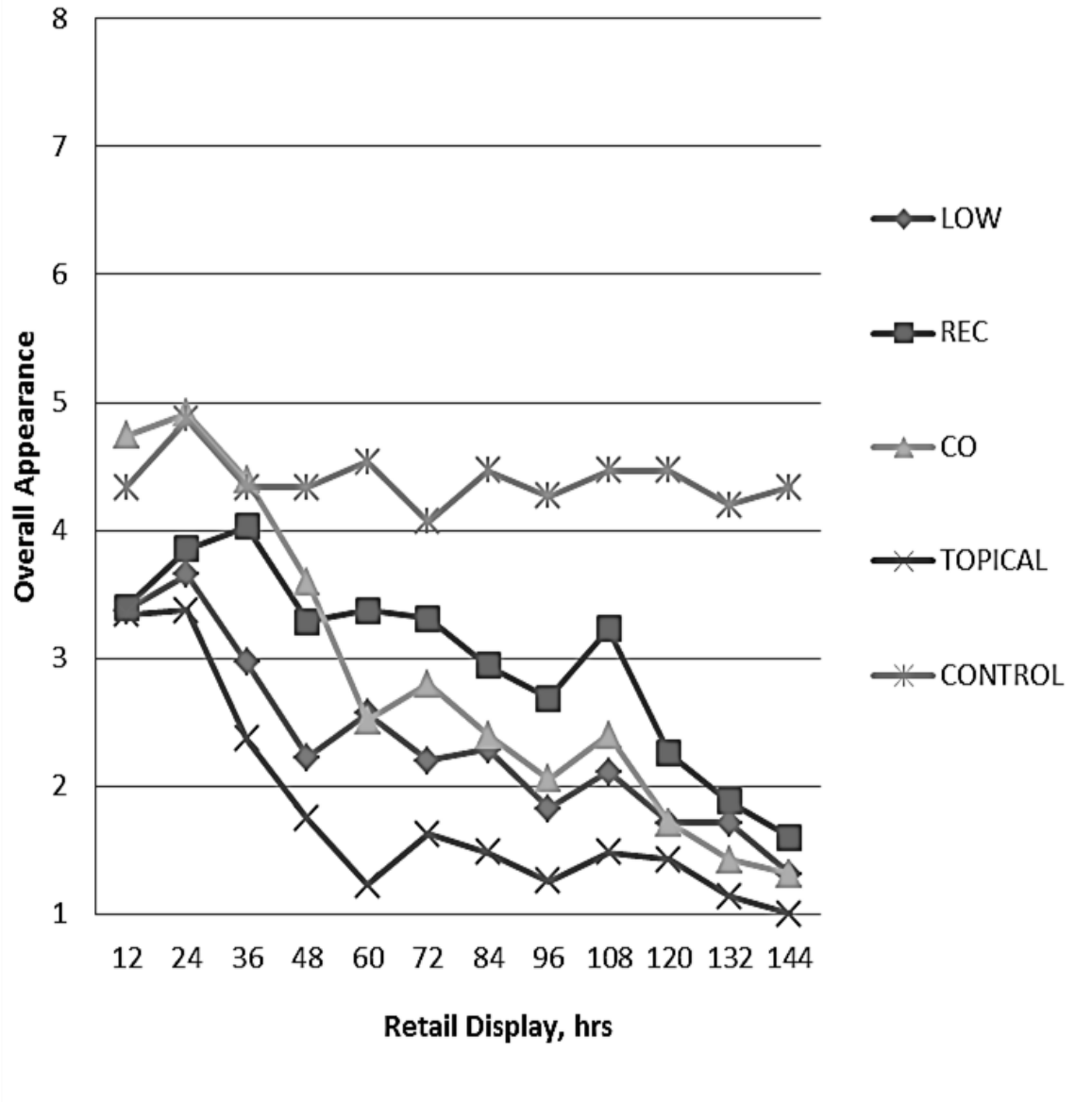


Figure 3.24. Subjective overall appearance evaluation of various moisture enhancement treatments of bottom round roast displayed over time. LOW = 60% injection of recommended level, REC = recommended injection level, CO = recommended level with .4% carbon monoxide incorparated into the solution, TOPICAL = no injection only topical overspray of recommended solution, CONTROL = salt and phosphate enhancement solution. Overall appearance scale: 8 = extremely desirable; 7 = very desirable; 6 = moderately desirable; 5 = slightly desirable; 4 = slightly undesirable; 3 = moderately undesirable; 2 = very undesirable; 1 = extremely undesirable (n = 7 observations/mean).



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	Painty / Fishy Falvor	Livery / Metallic Flavor

Initial and Sustained Juiciness	Tenderness	Connective Tissue Amount	Beef/Salty/Painty/Fishy/livery/Metallic
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	

OSU Meat Color Score Sheet

Evaluator: _____ **Project:** _____ **Date:** _____ **AM / PM**

Subject: _____

Muscle Color (MC)	Surface Discoloration (SD)	Overall Appearance (OA)
8 Extremely bright cherry red	7 Total Discoloration (100%)	8 Extremely desirable
7 Bright cherry red	6 Extensive discoloration (80-99%)	7 Very desirable
6 Moderately bright cherry red	5 Moderate discoloration (60-79%)	6 Moderately desirable
5 Slightly bright cherry red	4 Modest discoloration (40-59%)	5 Slightly desirable
4 Slightly dark cherry red	3 Small discoloration (20-39%)	4 Slightly undesirable
3 Moderately dark cherry red	2 Slight discoloration (1-19%)	3 Moderately undesirable
2 Dark red	1 No discoloration (0%)	2 Very undesirable
1 Extremely dark red		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			

VITA

Jesus David Ramos Sagarnaga

Candidate for the Degree of

Master of Science

Thesis: **ASSESSMENT OF AMONIA HYDROXIDE, SALT AND CARBON MONOXIDE IN IMPROVING THE RETAIL DISPLAY CHARACTERISTICS, PALATABILITY AND CONSUMER ACCEPTANCE OF CASE READY RETAIL CUTS**

Major Field: Animal Science

Biographical:

Education: Graduated from the Institute of La Salle in Chihuahua June, 1994; received Bachelor of Science in Veterinary Medicine from Autonomous University of Juarez, Mexico, May 2000; received postgraduate certificate in Medicine and Surgery of small animal from the Autonomous University of Mexico, Mexico March 2006; Completed the requirements for the Master of Science in Animal Science at Oklahoma State University, Stillwater, Oklahoma in May, 2011.

Experience: Raised in Chihuahua, Mexico, Employed by Veterinaria Ramos December 2000-July 2007; Employed by Chihuahua Beef TIF 414, August 2006-July 2007; Graduate research assistant and Teaching assistant, 2007-2009; Employed by National Beef Packing Co, July 2009 to present.

Professional Memberships: American Meat Science Association.

Name: Jesus David Ramos Sagarnaga May, 2011

Institution: Oklahoma State University Location: Stillwater, Oklahoma

Title of Study**: ASSESSMENT OF AMONIA HYDROXIDE, SALT AND CARBON MONOXIDE IN IMPROVING THE RETAIL DISPLAY CHARACTERISTICS, PALATABILITY AND CONSUMER ACCEPTANCE OF CASE READY RETAIL CUTS**

Pages in Study: 68 Candidate for the Degree of Master of Science

Major Field: Animal Science

Scope and Method of Study: Enhancement solutions have been used to improve the palatability traits of beef muscles to create a better experience for the costumer, the objective of the study is to evaluate three different enhancement solutions to improve color display characteristics as well as costumer acceptance for palatability and flavor profiles.

Findings and Conclusions: Enhancement with ammonium hydroxide improves juiciness, tenderness of case ready retail cuts when compared to a traditional enhancement solution (salt and phosphates), also helps in stabilizing color of case ready retail cuts in retail display over time for 24 to 36 h longer than cuts enhanced with salt and phosphates..

Name: Jesus David Ramos Sagarnaga Date of Degree: May, 2011

Institution: Oklahoma State University Location: Stillwater, Oklahoma

ADVISER'S APPROVAL: Dr. Deborah VanOverbeke