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Determining the effectiveness of rosemary essential oil on the shelf life of ground beef under different lighting conditions.

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Abstract

The objective of this study was to determine the effectiveness of rosemary extract on the shelf life of ground beef patties under different retail display conditions. Ground beef patties were produced from an 85% lean and 15% fat blend purchased from a local grocery retailer, finely ground through a 0.953 cm plate and separated into 151.2 g patties (*n*=64). Patties were randomly assigned into a control group (no antioxidants added) or a 0.20% concentration rosemary extract group. Patties were individually packaged using polyvinyl chloride overwrap. Antioxidant and control patties were randomly assigned into one of two lighting intensity groups (3000K v. 3500K). Patties were placed in a simulated retail display for 5 d under continuous light emitting diode (LED) lighting and rotated once a day within a multideck display case. Each day of retail display, a patty was removed from each treatment and immediately vacuum packaged and frozen at -20°C. Thiobarbituric acid reactive substances analysis (TBARS) was conducted to evaluate lipid oxidation of the ground beef patties, and color samples were taken each day using the Hunter Lab MiniScan Easy Spectrophotometer.

There was no three-way interaction between display day, antioxidant, and light temperature ($P > 0.05$) as well as no interaction between display day and light temperature ($P > 0.05$) and antioxidant and lighting temperature ($P > 0.05$). There was an interaction observed between antioxidant and day ($P < 0.0001$). A linear response of lipid oxidation in the control group was noted while the treated antioxidant group remained relatively consistent. Additionally, a main effect of antioxidant type ($P < 0.05$) and display day ($P < 0.05$) were observed.

In reference to color spectrometry, L* values presented an interaction between antioxidant and lighting intensity ($P = 0.0029$). This interaction indicates that lightness can be increased with the use of antioxidants when under higher lighting conditions as opposed to

3000K. A two-way interaction between day and antioxidant (*P* = 0.0003) was also shown in a* values, indicating that antioxidants create a 1-day separation between the control group on day 4. A similar relationship was found in b* values (*P* = 0.0008), with day 3 control values measuring at day 4 antioxidant values. Chroma values displayed an interaction between antioxidant and day (*P* = 0.0008), showing that control values were similar on day 3 as antioxidant levels on day 4, and hue data collected stated similar results (*P* = 0.0008) There was an interaction observed between antioxidant × day (*P* < 0.0001). Overall, a higher magnitude of difference was expressed through each progressive day of display, expressing a linear response of lipid oxidation in the control group, while the treated antioxidant group remained relatively consistent.

These interactions conclude that color instability and color degradation can be prevented with the introduction of antioxidants and the reduction of days of retail display. Adding an antioxidant to ground beef does decrease lipid oxidation when compared to ground beef that has not been treated with antioxidants. These data also suggest that antioxidants reduce lipid oxidation regardless of light temperature. As retailers opt for more bright white lights, antioxidants can still be used to successfully extend product shelf life and improve color stability, even in ground product.

Introduction

Background and Need

The use of natural alternatives as food additives to improve taste, texture, appearance, and shelf-life have become increasingly popular in recent years, both from a consumer and food industry perspective. Research into the topic of bacterial growth, when exposed to natural oils has been occurring since the 1970s, and with the growth in popularity and availability of natural oils in the last decade, inquiries into the role and function of these oils in the food industry have increased. Essential oils and naturally growing plants have been shown to act similarly to some current synthetic products that extend shelf life when used with fresh produce but provide negative olfactory responses due to unique odors and tastes associated with these oils (Rodríguez et al., 2015). These plant-based oils, however, are limited by these flavor compounds that results in certain antioxidants being better suited for specific food groups than others, and their synthetic counterparts provide a more cost efficient and more stable product that consistently performs higher (Pokorný, 2007) Studies have shown the potential for synthetic antioxidants to be harmful to health, and although the numbers are extremely low, adverse reactions to these additives is possible; however, natural alternatives cannot be determined to entirely safe either (Randhawa& Bahna, 2009; Pokorný, 2007). In recent years, research performed during animal processing has been underdeveloped, yet reports on the effects of oils utilized during nutritional supplementation of live animals and during processing practices have grown significantly. This form of shelf-life extension could potentially provide a multitude of benefits for consumers, including decreased prevalence of foodborne illness, alternatives to synthetic antioxidants, and the use of a cleaner label for consumers. While the driving force for more natural alternatives primarily appears to stem directly from the consumer side, potential outcomes of research within the beef industry or other food and beverage sectors, could provide novel and impactful results for a product that meets consumer needs and desires (McDonnell et al. 2013).

Problem Statement

While research has been conducted assessing the use of essential oils to extend the shelf life of food items, such as fruits and vegetables, similar research on meat products in combination with essential oils is lacking, especially when factors such as lighting are also evaluated. With the growing interest within the consumer population to only have "natural" food products on shelves, discovering a means of using exclusively "natural" ingredients is a new but increasingly more pertinent step presented to food producers on all levels. Focusing on alternatives can not only lead to an increase in consumer satisfaction and interest, but also provide the industry with an additional opportunity to reduce product and monetary loss. The current research reveals mixed results in increased days on using oils to increase shelf life with some of the most recent studies citing an increase of anywhere from three to nine days in shelf life to none (Behrooz et al., 2016; Wang et al., 2020).

Purpose Statement

The purpose of this study was to explore potential natural alternatives such as essential oils to enhance the shelf life of ground beef while maintaining the overall visual and taste appeal. A secondary focus of determining the effectiveness of essential oils under different lighting conditions was also evaluated.

Research Objectives

1. To determine the effectiveness of rosemary essential oil added during grinding on increasing the shelf life of ground beef in a retail case under two lighting conditions.

2. To determine to what degree the addition of rosemary essential oil and lighting intensity alter appearance of the meat (positively, negatively, or neither).

Research Hypothesis

1. If rosemary essential oil is added to ground beef in a refrigerated state under 3000 K lighting, then the shelf life of the beef will be significantly increased without changing the appearance of the meat.

Literature Review

While research on the use of essential oils and its' effects on the perseveration of food is relatively well established, it is usually related to a specific aspect of the food product. Many studies focus on one or two aspects of the overall effects of essential oils, such as benefits on shelf life, color alterations, effects on specific bacterial or viral growth, or the resulting chemical change. Other studies choose to take a less traditional approach through a focus on preparatory steps before the product is produced, such as in the beef industry. Throughout the research strands, however, there are common results that encourage a continued search for the most beneficial essential oil to improve shelf life.

Shelf Life Impact

The average shelf life of aerobically packaging fresh ground beef in retail display has been concluded to be between five to seven days of retail display, but the addition of outside effects influences this number both positively and negatively (Delmore, n.d.). Lighting is a major factor affecting the shelf life of beef, along with other perishable goods such as dairy products (Limbo et al., 2020). Limbo et al. (2020) and Giest (2015) both concluded that milk and beef products expressed the longest shelf life in complete darkness. However, in retail situations, dark storage is not plausible, and thus the addition of lighting must be taken into account. Temperature also has a significant effect on the shelf life of the product. A study conducted by Jeremiah and Gibson (1997) determined that the maximum potential of shelf life is attained through minimizing meat temperature without freezing the substrate.

Color deterioration also plays a significant role on shelf life and is commonly the measure of shelf life in beef studies. Because color is one of the consumer's most important aspects of a product, the shelf life of a cut of meat can be greatly shortened due to a perceived lack of acceptability rather than a true safety concern. Oxidation plays a major role in color development. Myoglobin, the pigment most responsible for the desirable red color in beef, can be oxidized into metmyoglobin which creates a brown color (Zerby et al. 1999). Deoxymyoglobin, the pigment that gives meat a purplish color, converts into oxymyoglobin when exposed to oxygen by exposure to oxygen in the air. The ideal color of fresh beef is obtained through proper use of blooming, the process in which deoxymyoglobin is converted into oxymyoglobin (King et al., 2023). However, this color can also be affected by a number of intrinsic factors including muscle type, final pH, water holding capacity, and the composition of the muscle itself, as well as characteristics innate to the animal itself such as diet, age, stress, and gender (King et al., 2023). This makes it more difficult to specifically identify a successful means of limiting or enhancing color change. However, when deoxymyoglobin converts into oxymyoglobin, oxidation creates a brown color (USDA FSIS, 2013). Once meat has reached the brown state, consumers deem the product unworthy for consumption, limiting the product's overall shelf life. Many of the current packaging techniques include oxygen permeable wrappings which constantly allow the introduction of oxygen into the environment. This allows for continued oxygenation rather than a fixed amount from a sealed package, contributing to changes in meat coloration.

Essential Oils

Though research indicates essential oils are beneficial in extending the shelf life of produce and cuts of meat, research to determine the most effective essential oil continues. When deciding which oil or oils to use, factors such as the potential change in taste or appearance must be taken into consideration. Thyme and rosemary are commonly chosen for research, likely due to the common use of these flavors in food preparation and their antioxidant capacity. Sirocchi et al. (2017) and Nowak et al. (2012) both used rosemary oil in individual studies, finding that the use of the oil was beneficial in reducing bacterial growth and therefore extending the shelf life in beef cuts. However, Nowak et al. (2012) reported that the use of thyme and rosemary oils in the study generated negative off flavors and appearances as conducted by a trained taste panel making it impractical for commercial use. Conversely, a study conducted by Mehidizadeh et al. (2020) determined that the use of both pomegranate peel extract and thyme essential oil received positive results in sensory tests and resulted in increased storage life. The variation in results could have been related to the concentration of the oil used or other factors not presented in the studies.

The sensory aspect of essential oil use is not always included in studies focused on increasing shelf life and thus creates a gap in the research for determining whether or not the essential oil will be detrimental to sales. For example, a study exploring the usefulness of tea tree oil against the growth of *Listeria monocytogenes* determined that the oil did show potential for preventing the spread of the bacteria (Silva et al., 2019). While the study was beneficial in determining potential shelf-life benefits, the sensory component was ignored and limited the usefulness of the study on a broader scale.

Studies focused outside of the meat industry tend to choose other oils than the ones presented based on similar reasons. Citric essential oils, those found in citrus fruits such as lemons or oranges, were predominately used in fruit studies. Lemon and orange essential oils were used in a study conducted by Rodríguez et al. (2015) in association with minimally processed mango. The study determined that lemon oil was more positively received in a taste test compared to orange essential oils and recommended the edible coating should be considered for commercial use. Similarly, in a study conducted to extend the shelf life of fresh cut apples, the use of citral, an oil found in citrus, and eugenol (more commonly known as clove oil) increased the shelf life of the apples (Guerreiro, 2016). It was concluded that the use of citral alone could not be used in commercial settings such as retail markets due to the adverse taste it created in the study. Similarly, in a study conducted on the quality of frozen beef patties with clove essential oils, researchers found that the oil did increase the shelf life, and only resulted in negative sensory results at high concentrations levels (Abdel-Aziz et al., 2015).

Packaging

Studies conducted on the effectiveness of essential oils also contain a focus on different packaging methods. There are multiple accepted forms of packaging for beef products. One is the modified atmosphere packaging which alters the environment of the meat through varying percentages of oxygen, carbon dioxide, carbon monoxide, or nitrogen to prevent extra growth of bacteria and maintain a certain color, for beef this is generally bright red (Huang & Hwang, 2012). This method has been shown to extend shelf life. However, packaging methods combined with one or more essential oils have been shown to further increase shelf life (Nowak et al., 2012). In addition to disposable packaging, edible coatings have become increasingly popular, especially among fresh cut fruits. Edible coatings can be defined as consumable materials that provide a moisture barrier and extend the appearance life and shelf life of the food product to which it is added (Trinetta, 2016). Guerreiro et al. (2016) observed in combination with citral and eugenol, edible coatings increased the shelf life of apple slices. A study conducted over the extension of shelf life of beef using *Plantago major* seed and *Anethum gaveolens* (dill) essential oil in an edible coating further confirmed that the results between fruits and meat are generally interchangeable (Behrooz et al., 2016).

Aerobic and anaerobic packaging have also been studied in conjunction with one another over the same essential oil. A study using rosemary essential oil found that the aerobically packaged meat had a shelf life of seven days while the nonaerobic packaged meat was only acceptable for five days (Sirocchi et al., 2017). It was shown in the same study that the nonaerobic packaged meat resulted in a significant change in the color of the meat. Similarly, atmosphere-altered studies have shown to be beneficial in combination with essential oils with a significant increase in shelf life (Nowak et al., 2012). In a study assessing the shelf life of broccoli utilizing different lightings and packaging materials, results indicate that the use of modified atmosphere packaging was the most beneficial in decreasing deterioration of the product (Castillejo et al., 2020).

Lighting

Research focusing on the effects of shelf life on ground beef is relatively well developed, especially when using essential oils. Lighting has become more of a research focus in recent years, as well, to determine if lighting has any influence on the shelf life of the product. Several studies have determined that beef exposed to light-emitting diode (LED) lighting rather than to fluorescent lighting resulted in better appearance and shelf life (Cooper et al., 2016). Giest (2015) reported that the use of LED lights resisted a change in meat discoloration over a longer period. Steele et al. (2016) concluded similar results in a study conducted with pork loin chops, beef steaks, and ground steaks. However, there was no data collection in regards to lipid oxidation during these studies. A combination of both essential oils and lighting considerations can lead to a potential significant increase in the shelf life of not only ground beef but other major cuts of beef in the market.

Pre-Harvest Studies

Little research has been conducted on the use of essential oils in feed prior to slaughter to increase the shelf life of beef. Wang et al. (2020) determined that the use of oils in finishing cattle showed no positive change for the shelf life of ground beef or ribeye steaks. The study does mention that while there are no positive changes, there are also no negative changes, thus presenting the potential for preventative oil supplements to show benefits in the future, although several hurdles will have to be overcome in order to prevent the saturation of the essential oils in the rumen.

While fewer studies have been conducted with the use of essential oils in particular, there has been a focus on the development of diets that show impactful results in postmortem processing. One of the major contributors to this is the addition of vitamin E as a dietary supplement. Studies have been conducted that prove that the addition of supranutritional vitamin E prevents the onset of oxidation, extending the days of shelf life before color change became obvious (Mitsumoto et al., 1991). This discovery, along with the use of essential oils in packaging, could create a significant increase in the shelf life and appearance of not only ground beef, but all retail cuts.

Growth and development of this topic has increased within recent years with many in the industry turning a focus to the potential benefits of essential oils for increasing shelf life. Other factors such as what retail display to use and lighting considerations will continue to improve the shelf life of beef.

Methodology

The strength of lighting differs between retail locations and because of that, the variations in shelf life could be further altered (positively or negatively) even with the successful use of essential oils. Focusing on to what extent the shelf life of ground beef is altered by the use of specific essential oils and to what extent lighting impacts the shelf life could further explain differences found in laboratory studies and in applied retail settings.

Research Design

A true experimental quantitative approach was used to accomplish the goals of this study, which include determining the effectiveness of essential oils on ground beef storage in conjunction with alterations in lighting intensity. This experimental approach allows for statistical validity between the use of essential oils, lighting, and ground beef (Phan et al., 2017). The causality that was expected was that an extension of shelf life for ground beef treated with essential oils in combination with a lower light intensity would result after a common period in retail display. Through previously conducted research, the positive correlation between shelf life and essential oil, as well as between shelf life and lower lighting intensity, implies the possibility of synergism when the two are combined.

Ground beef was purchased locally with an 85% lean and 15% fat ratio, fine ground through a 0.953 cm plate and separated into 151.2 g patties (n=64) using the Hollymatic Super

Patty Machine. During grinding, Kalsec® Oleoresin Rosemary, Herbalox® Brand XT-25 was added with a concentration of 0.20% (Keokamnerd et al., 2008). Patties were randomly assigned to one of two treatments, a control group and a group treated with essential oil. The patties were then individually packaged in foam trays with an oxygen permeable polyvinyl wrap. Patties, within antioxidant treatment, were randomly assigned to two different lighting temperatures (3000 K v 3500 K) in retail placement. Six batches were created with three antioxidant batches per antioxidant treatment. A completely randomized split plot designed was used. One batch served as the whole plot and lighting served as a whole plot. Ground patties were subjected to a simulated retail display for five days under continuous fluorescent lighting at 4 degrees Celsius. Patties were rotated once each day following TBARS and color data collection. These patties were rotated randomly within the shelving of the display case, moving internally in the shelves as well as levels in the case.

Rigor

Rigor for this project was established through focused attention to the internal and external validity through the methodology of the experimentation. Removing individual selection when forming treatment groups is essential to preventing possible unintentional bias and thus increasing the rigor of the study conducted (Mackieson et al., 2019). Internal validity was established through the complete randomization of the treatment groups through the use of an online random sorter. This prevented the possibility of one treatment group containing patties only from one specific package and removed the possibility of the patties being sorted based on texture or color. The treatment groups were randomly assigned rather than establishing treatments from appearance or order of preparation. The randomly generated treatment groups prevented possible underlying bias towards certain traits and their use in the experiment. Internal validity was also established through the use of only locally purchased beef which was then finely ground in a single location. All beef was separated in the same facility and was packaged using the same overwrap packaging, and all patties were packaged at the same time, eliminating the possibility of slight differences in atmosphere or packaging technique.

External validity was established through the continual upkeep of the measurement machines, both the Hunter Lab MiniScan EZ spectrophotometer and necessary equipment for the TBARS analyses. TBARS analyses where conducted using the methodology presented in Buege and Aust (1971) with modification by Luque et al. (2011) as a previously accepted means of determining the oxidation of the beef after each day of retail display. The protocol to sample the products further solidified the external validity through selecting a specific time to test all of the patties once a day during the study. Patties were selected at random from their respective treatment groups to provide a representation of the results. Due to the similar nature of meat processing throughout the United States and required standards for ground beef that can be sold and purchased in retail locations, rigor of this study was continually established by its ability to be repeated with ground beef purchased from any location, including those outside of the Northwest Arkansas area.

Population and Sampling

The population of the study was determined through beef that was 85% lean and 15% fat and purchased from a local grocer. The finely ground and formed patties were then separated into treatment groups through a simple random sampling procedure performed by an online random generator. The treatment groups were then also subjected to a simple random sampling procedure performed by an online random generator to determine the treatment that each would receive. Every day after display, a sample from each treatment groups was taken from the specific treatments and randomly selected from the patties present through a randomly generated table provided by an online random generator to provide a representative of the entire package.

Data Collection

Ground beef patties were displayed in a simulated retail case for five days with the control and antioxidant treatments randomly assorted throughout the two separate lighting cases. Shelving display was used for the current experiment in an open-air shelving display case. During each day of retail display, instrumental color of patties was determined using the Hunter Lab MiniScan EZ spectrophotometer. L*, a*, and b* values were taken in order to determine lightness, redness, and yellowness respectively, hue to measure the vividness, and chroma to determine saturation (King et al., 2023). Hue was calculated by taking the arctangent of the b* values divided by the a* values, while chroma was calculated by squaring both a* and b* values, and taking the square root of the sum, according to the American Meat Science Association Guidelines (2023). Three measurements were taken per patty and averaged together to provide an overall color measurement for each patty.

Each sample was then thawed for 10-12 hours to 5℃, placed in liquid nitrogen, and powdered using a Nutribullet blender. 10 g of sample was weighed into a 50 ml conical tube and TBARS was analyzed through the modified procedure of Buege and Aust (1978) as described by Luque et al. (2011). A standard curve for the assay was run for each day of testing. Samples were blended with 30 mL deionized water then centrifuged. Two mL of the supernatant was removed and added to a 50 mL centrifuge tube with the trichloroacetic acid reagent and butylated hydroxyanisole were added. Samples were heated, cooled, and centrifuged. Two 1 mL samples were added to a 48 well plate then analyzed.

Results and Discussion

Instrumental Color Analysis

There were no three-way interactions observed for any of the traits evaluated ($P < 0.05$). There was no interaction between day and antioxidant presented in L* values ($P > 0.05$). There was an interaction between antioxidant and light ($P = 0.0029$) indicating that lightness value increases as lighting increases. When antioxidant treatments are given, there is no difference between the groups at 3500K; however, at 3000K, antioxidants show a significant increase in lightness. There was a main day effect shown ($P < 0.0001$) with a predominate linear decline in L* as day progressed, with the exception of D0, implying that the addition of the oleoresin antioxidant could have played a role in the lower lightness value. There was also no interaction between day and light ($P > 0.05$) or between light and antioxidant ($P > 0.05$) in a* values. A two-way interaction was found between day and antioxidant ($P = 0.0003$). The antioxidant group consistently sees higher redness throughout the trial, with each day decreasing in value; however, the D3 control values are the same for D4 antioxidant values, implying that with the antioxidant treatment, a day of retail display may be gained in terms of redness. There was also no interaction between day and light ($P > 0.05$) or between light and antioxidant ($P > 0.05$) in b* values. A two-way interaction was found between day and antioxidant ($P = 0.008$). On D3, the control treatments had statically similar b* to the antioxidant treatments on D4. This trend can be seen throughout the rest of the study with the antioxidant group reaching similar yellowness one day behind the treatment group. A main effect of lighting temperature was also expressed ($P = 0.0234$), stating that lower lighting intensity resulted in higher yellowness regardless of day or antioxidant. Regarding chroma, there was no interaction between day and light ($P > 0.05$) or between antioxidant and light ($P > 0.05$), but there was an interaction between antioxidant and day (*P* = 0.0008). At D3 in the control group, the saturation values are statically similar to D4 values in the antioxidant group. As seen with the other measured data, using the essential oil prolongs the degradation of the measured chroma values, which could provide an additional day during retail display in regards to the saturation of meat color. There was no light main effect presented (*P* > 0.05). There was no interaction between day and light (*P* > 0.05) or between antioxidant and light, however, a hue angle day and antioxidant interaction was presented (*P* = 0.0008). This interaction showed that on D3, control groups presented statistically similar values as antioxidant groups on D4 and continued in a similar pattern until the end of the trial. This once again presents the notion that with the introduction of antioxidants, there could be an increase of one day in the display life of the product in regards to the prevention of instrumental discoloration. There was no main effect of light found (*P* > 0.05).

Thiobarbituric Acid Reactive Substances Assay

There was no three-way interaction between display day, antioxidant, and light temperature (*P* > 0.05) as well as no interaction between display day and light temperature (*P* > 0.05), and antioxidant and lighting temperature (*P* > 0.05). No effect of lighting temperature was observed (*P* > 0.05). There was an interaction observed between antioxidant and day (*P* < 0.0001). Overall, a larger separation between control and antioxidant was shown through each progressive day of display, expressing a linear response of lipid oxidation in the control group, while the treated antioxidant group remained relatively consistent. Additionally, a main effect of antioxidant type (*P* < 0.05) and display day (*P* < 0.05) were observed. Each replicated antioxidant treatment expressed lower lipid oxidation than the control, regardless of lighting intensity (*P* < 0.05). Furthermore, a reduction in display day yielded a net reduction in lipid oxidation, regardless of lighting temperature or antioxidant supplementation (*P* < 0.05).

Limitations

Because the ground beef was purchased through a third party, the age of the product was not determined before the beginning of the study. This limits the capacity for extended data collection. The trial duration was set at five days, however, due to not including bacterial collection and analysis in the procedure, bacterial load and thus food safety of the ground beef cannot be determined after the simulated retail display. Taste panels were also not conducted during this study, thus the potential changes in flavor due to the added antioxidant cannot be collected further limiting the industrial application of this research.

Conclusions

Throughout the duration of this study, antioxidants continue to behave in similar ways as recorded in the literature, regardless of the introduction of lighting. The introduction of antioxidants allows for the prolongation of color values throughout a display period, however based on the results of this study, there is no significant relationship between antioxidant use, lighting intensity, and day. When considering different means of maintaining meat color, antioxidants can still be utilized to achieve this goal. The antioxidant effect found in essential oils such as rosemary continue to prove similar results as predicted regardless of lighting intensity. Adding an antioxidant to ground beef decreases the lipid oxidation over the period of five days as compared to ground beef that has not been treated. Antioxidants reduce lipid oxidation regardless of the lighting intensity as suggested by the data. As retailers and consumers continue to search for more ways to reduce the oxidation of their meat products and increase the shelf life, antioxidants can still be used in ground products to achieve these results.

Benefits to the Industry

Increasing the shelf life of meat products provides a significant amount of potential benefits, from decreasing risk of foodborne illnesses to consumers to providing healthier alternatives to previously accepted synthetics. With the current climate of consumers looking for natural alternatives, the use of essential oils has not only been accepted but welcomed into the commercial world. As well, the extension of shelf life could continue to decrease the amount of food product waste each year, which currently causes a significant amount of financial loss to both the consumer and the food industry (Geist, 2015).

According to a study conducted over the cost of consumer food waste, the average American wastes around a pound of food a day (Conrad et al., 2018). This is a large amount when considering not only personal, but on a country-wide scale, the amount of food wasted daily as well as annually is a significant concern. Color is considered to be one of the top factors in consumer decision making (Djenane et al. 2001), and because of such, making sure that the color and overall appearance of the meat is minimally altered is a major factor in preventing product loss. Determining which essential oils can increase the shelf life of the product while minimally altering the sensory aspects can help to increase the consumer satisfaction and prevent the disposal of food both in the retail realms and from the consumer perspective. Increasing the opportunity for consumers to purchase a product while keeping it safe is one of the key factors in decreasing both product and financial loss.

Table 1: Least square means of treatment group for TBARS analysis

Treatment	Malondialdehyde mg/kg
Antioxidant	0.110[a]
None	0.237[b]
SEM	0.00613
P-value	<.0001

[ab]Least square means without a common superscript differ ($P < 0.05$).

Table 2: Least square means for display days of ground beef for TBARS analysis

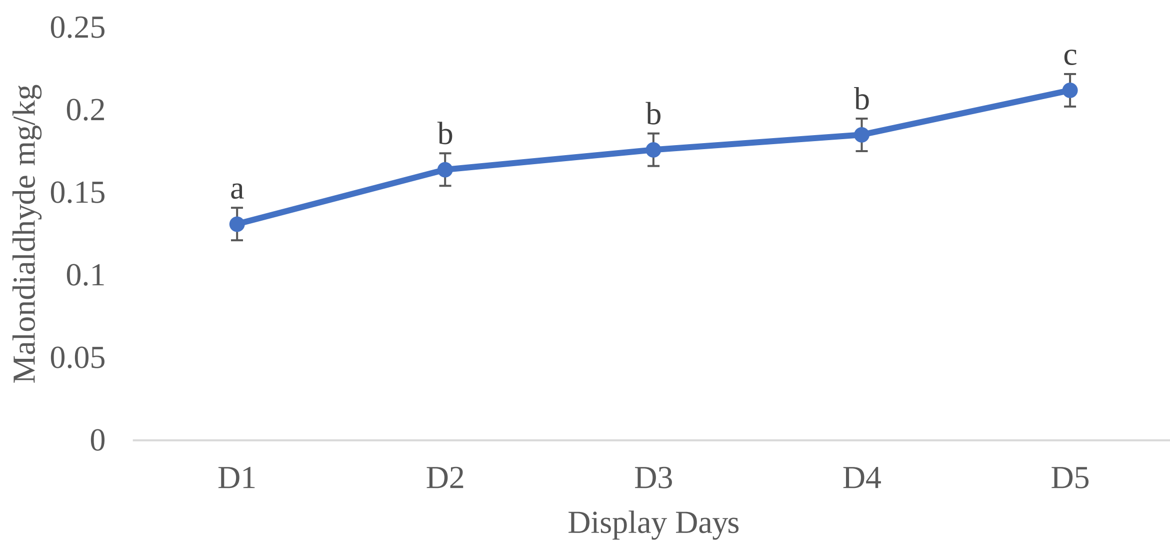


Figure 1: Interaction of antioxidant and display day on TBARS analysis

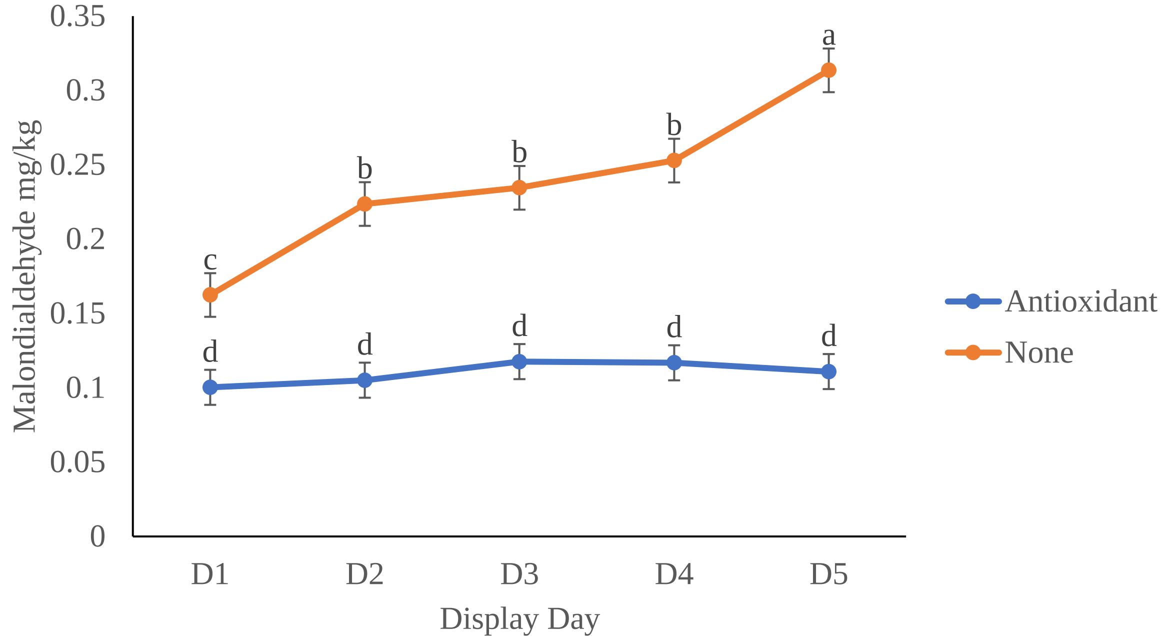


Figure 2: Interaction of antioxidant treatment and lighting intensity on L* value

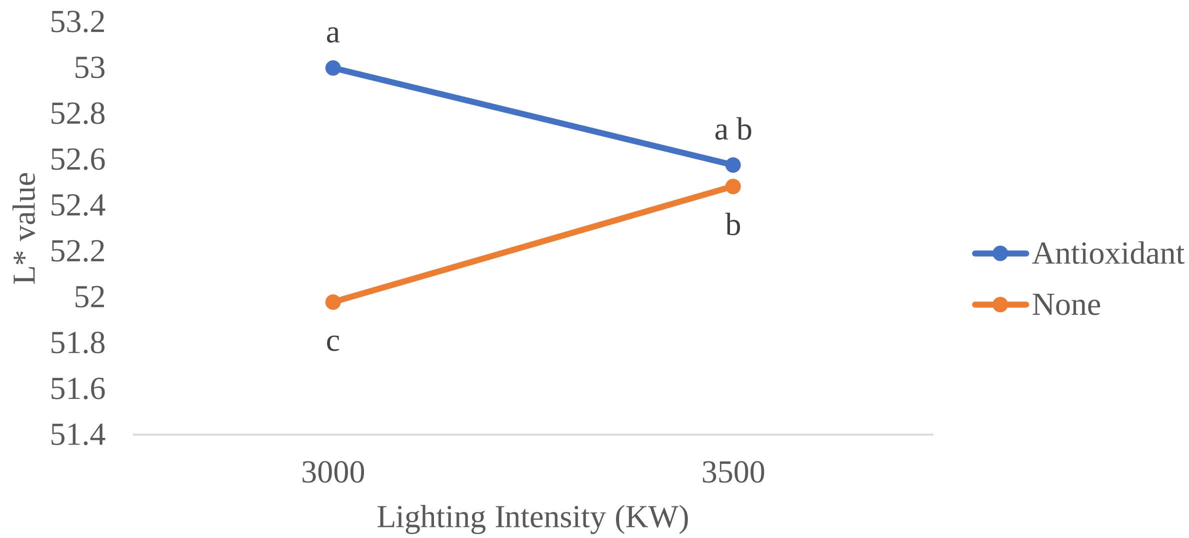


Figure 3: Interaction of antioxidant treatment and display day on a* value

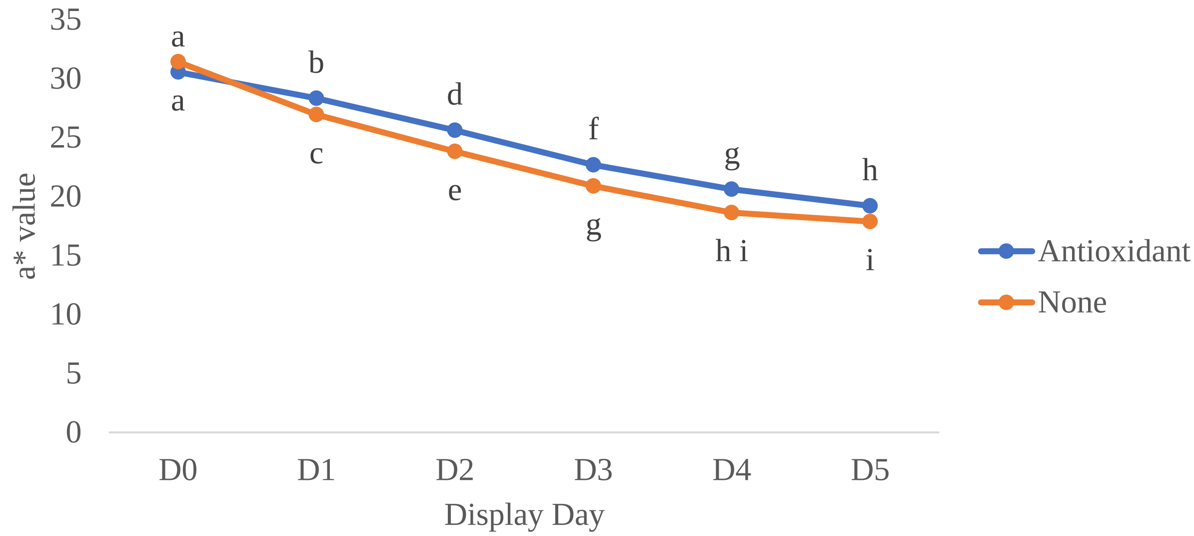


Figure 4: Interaction of antioxidant treatment and display day on b* value

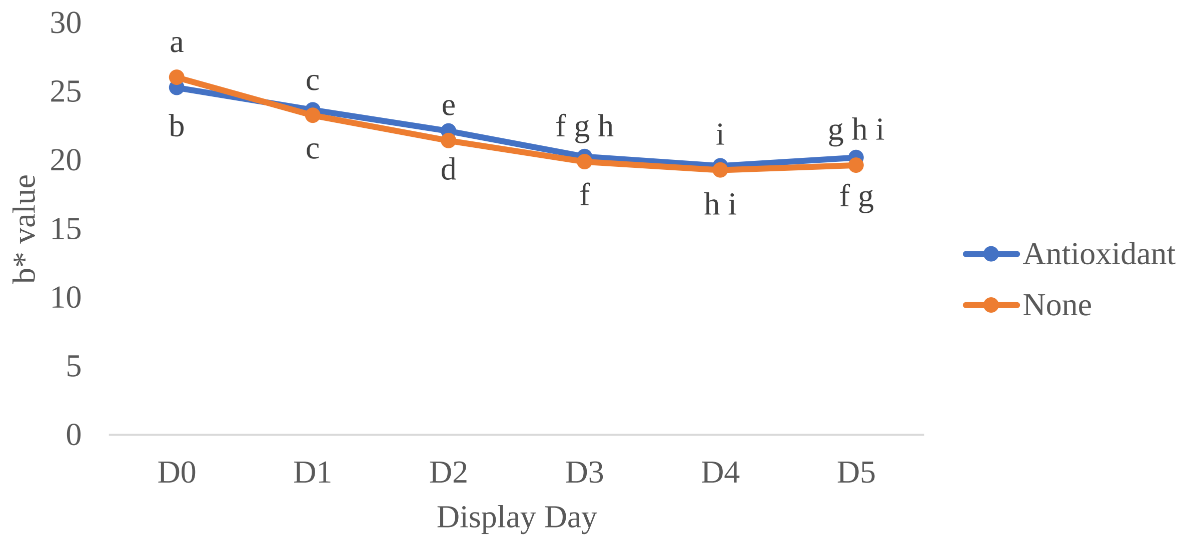


Figure 5: Interaction of antioxidant treatment and display day on hue angle

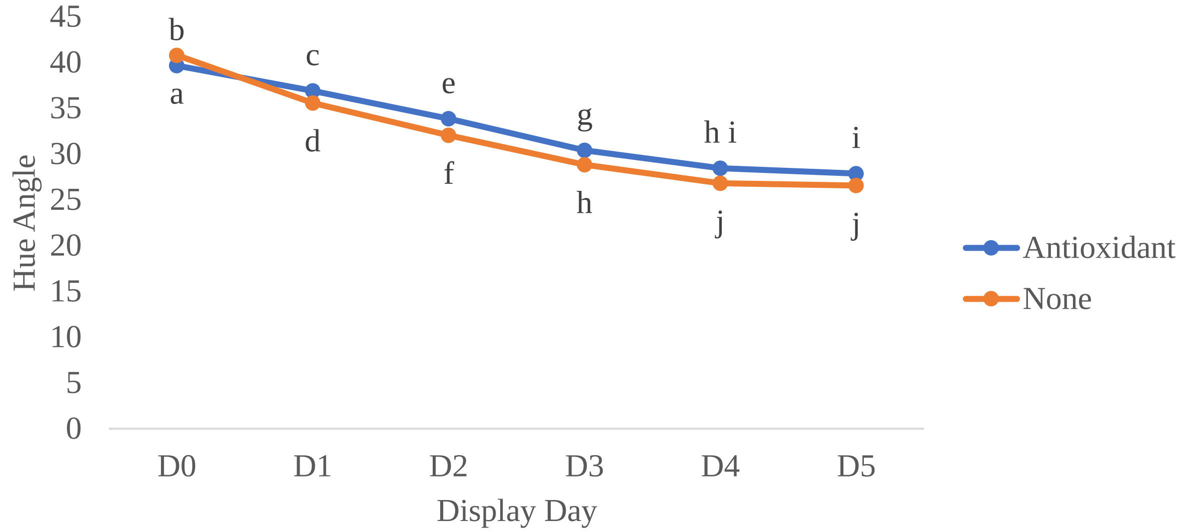
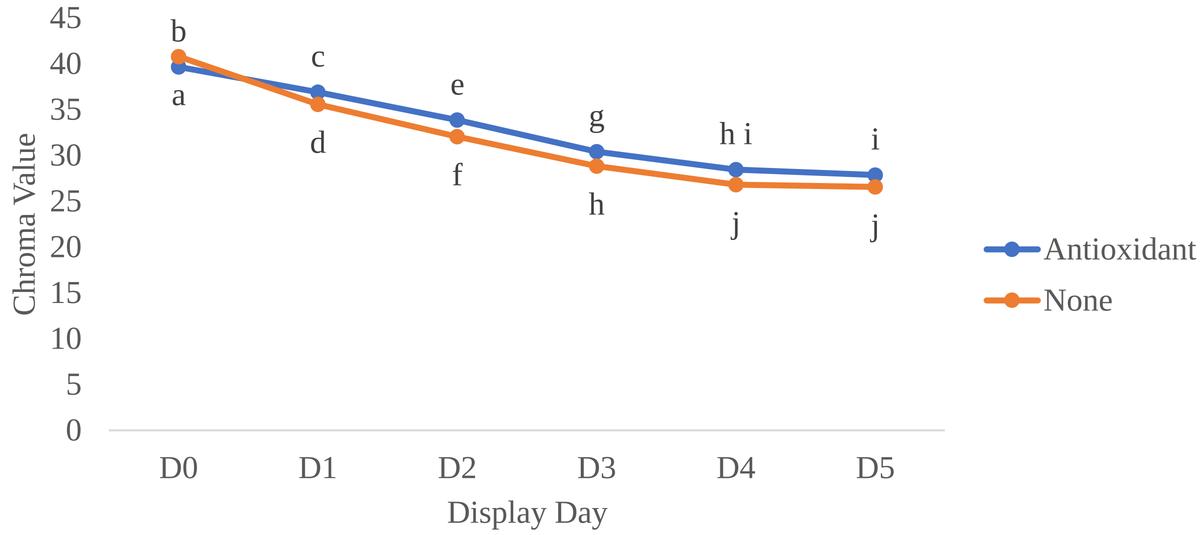


Figure 6: Interaction of antioxidant treatment and display day on chroma value



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