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Effects of Retail Case Environment and LED Lighting Temperature on Color and Oxidation of Previously Frozen Ground Beef Patties

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Abstract

The purpose of this study was to investigate different environments of retail cases and LED lighting temperatures to observe how these conditions affect oxidation of previously frozen ground beef patties. Coarse ground beef (85% lean) was purchased from a commercial beef processor, fine ground through a 10 mm grinder plate, and then formed into 1/3-pound patties with an automatic patty forming machine. Patties were then randomly assigned to four different treatments: open-front display cases with 3000 K lighting (OPEN3000), open-front cases 3500 K lighting (OPEN3500), reach-in door display with 3000 K lighting (CLOSED3000), and reach-in door display at 3500 K lighting (CLOSED3500). Nine patties from each batch were assigned to each treatment combination. Patties were displayed for 7 days. The results indicated that no differences were observed between light treatments, and no differences were observed from case. Case*Light is the only interactive effect of significance ($P<0.05$). It was observed that Closed 3000 had the highest TBARS value,($P< .0001$) Closed 3000 had the highest TBARS values, and Closed 3500 had the lowest TBARS values, and the Opens were intermediate. It was observed that as the number of days spent in a retail display had an effect on lipid oxidation and color. There is a gradual increase in malondialdehyde levels as the days of being in the retail display also increase. No differences were observed between light treatments and no differences were observed from case. From the case study we can conclude that case and light are interactive of one another. Further research needs to be conducted; to see which specific groups are driving oxidation.

Key Words: color, color stability, ground beef, lighting, LED lighting, retail display

Introduction

Background and Need

Ground beef is the most popular cut of beef in the US, comprising 42% of beef purchased at retail and food service (Beef Issues Quarterly, 2016). Because the structure of the beef has been compromised by the grinding and mixing processes, it is also among the least shelf-stable fresh products in the case. Maximizing the shelf life of ground beef and all retail cuts in the retail display case will increase the value of beef for all segments of the industry.

Coffin-style and open-front retail display units are some of the least energy-efficient storage and display systems in the retail store. The Department of Energy regulates the cases energy use and mandates changes in case technology to improve energy efficiency with new cases and new stores. Reach-in door cases have been used in several segments of grocery products like frozen foods for several years, but until now, reach-in cases were not designed to market fresh meat. Reach-in door cases minimize the temperature variation around the product and have the potential to improve shelf life in ground beef and improve food safety.

Another technology that has been shown to reduce the impact on energy consumption is LED lighting in display. Not only do LED lights require less energy to illuminate the cases, LED lighting creates lower temperatures in the case resulting in fewer compression cycles per hour and less energy needed to keep the cases cool. Compared to fluorescent lighting, LED lights resulted in improved visual color in ground beef, beef strip steaks, ground turkey and pork chops during display (Steele et al., 2016). LED lighting is available in multiple temperatures and the optimal LED lighting temperature has not been determined.

It is very common for people to freeze their ground beef if it cannot be cooked before it reaches the end of shelf life. Since there has been an increase in the cost of meat, freezing has also become a method used to store large amounts of meat within the home of many. Now that it's common for people to buy half or a whole steer, they should also know the best types of packaging to properly store their meat. Freezing storage enables deleterious changes which can reduce meat quality depending on storage time, temperature, freezing rate, and protective packaging used. The correct packaging for frozen meat will ensure that the meat is safe and will taste as fresh as possible (Brewer, M. S., and WU, S. Y. 1993).

Problem Statement

According to the FAO, every year 1.3 billion tons of food produced for human consumption is waisted worldwide (Roodhuyzen, Luning, Fogliano, and Steenbekkers 2017). It is beneficial to both the consumer and producer to research the reason why so much food is wasted in the United States every year. Economically, there is the cost of food waste itself; however, the associated inefficiencies in the supply chain, storage, upward pressure on prices, and reduced profits are also affected (Roodhuyzen, Luning, Fogliano, and Steenbekkers, 2017).

Purpose Statement

In the United States, supply chain food waste happens at all phases, however in terms of waste prevention, the store front phase has the greatest potential for waste reduction (Dreyer, 2019). The purpose of this research was to evaluate different retail case types and the impact of lighting intensity on ground beef from frozen storage. Addressing retail cases and retail lighting environments may aid in the reduction of food waste since consumers are likely to not purchase a discolored product.

Research Questions

- What are the effects of the type of retail case environments and lighting temperature (LED versus LED) on the oxidation of previously frozen ground beef patties?
- Can retail case environments and LED lighting temperatures be optimized to improve ground beef shelf-life over time?

Definitions

Shelf-life: The period of time between packaging of a product and its end use when product properties remain acceptable to the average consumer.

LED lighting: refers to the visible light emitted by an electrical component or device that has two electrodes, a cathode and anode, that facilitate the flow of electric current, hence the name Light-Emitting Diode.

Fluorescent (FLS) lighting: refers to the light generated from the collision between atoms and free accelerated electrons. The light is formed when the electrons collide at high energy levels.

Color stability: refers to the ability of an item, in this case meat, to maintain the properties of color and color rendering over its life.

Literature Review

Nearly 24% of food produced for human consumption is wasted worldwide (Stancu, Haugaard, andLahteenmaki, 2016). Past studies have researched what type of consumer waste food, what circumstances make consumers waste food, and how to change consumer habits to reduce food waste. Research has been conducted from the perspective of the supply chain to identify sources of waste. There is also research looking into packaging to extend shelf life and the addition of certain preservatives to lengthen shelf life. There is not much research on using different lighting sources and retail display cases to extend shelf life and reduce the waste of ground beef in retail store settings.

Open- and Closed- Door Retail Cases

Research has found that closed-door retail cases might be the equipment of the future for keeping temperature uniform (Frias et al., 2020, Brenes et al., 2020), reducing food safety risks (Brenes et al., 2020), upholding desirable appearance of retail meats (Greer and Jeremiah, 1980), reducing energy cost (Frias et al., 2020), and reducing food waste (Brenes et al., 2020).

Although closed-door retail cases might be the future, open-front are the most commonly used equipment. They are popular because customers can gain access the products without barriers. However, warm and humid air infiltration inevitably leads to temperature heterogeneity within the cabinets. This heterogeneity can cause food quality deterioration and high electrical energy consumption (Chaomuang, 2017). A study was carried out to see if customers in the USA would be opposed to closed-door retail and the result came back that there would be no affects in product sells if stores started using closed doors. (Frickle and Becker, 2010).

Temperature variation within retail display cases

Perishable in nature food must have an interior temperature of no less than 2°C and no more than 4°C in order to meet FDA Food Code requirements (Djenane et al., 2006). It was found that enhancing beef shelf life was possible when the temperature in retail cases was properly controlled by Schratz et al (2013).The FDA Food Code threshold temperature for highly perishable food is 5 degrees Celsius (Frias et al, 2020) and it is suggested that display cases sustain meats at core temperatures from 2 to 4 degrees Celsius (Greer and Jeremiah., 1980). Greer and Jeremiah (1980) conducted a study looking into the effect proper control of retail case temperature has on refining beef shelf life. Thirty-five wholesale beef ribs were matured for six days before being frozen at - 20 C. Before the experiment, 50 steaks were sliced, wrapped in an oxygen-permeable polyvinyl sheet, and placed in five distinct display case blower temperatures. They were measured for four days of retail display and thirteen blower temperature readings were obtained for each of the five distinct display case blower temperatures (Troy & Kerry, 2010). Hyper pigmentation and retail acceptability of the steaks were assessed by a three-member sensory panel, who evaluated the steaks for discoloration and retail acceptability. Results show that steak surface temperature averaged around 9 C difference between the steaks surface temperature than and that of the incoming blower air and in turn resulting in lower bacterial generation time (by 0.7 hours) which is more than half a day reduction in steak shelf life. Greer and Jeremiah (1980) reported that thermometer temperature is not necessarily the correct temperature of the meat animal product. There is variation in temperature when the thermometer is influenced by incoming blower air. These outcomes could be continued to show the variation in both open-door and closed-door retail cases.

A study conducted by Brenes et al. (2020), found that temperature variation can be lessened with closed-door retail cases. There was a variance in temperature in open- and closed- retail cases, and product position within the case. The results showed that the open-door cases and the meat positioned near the top front of the case documented the highest temperatures.

Efficiency within retail display cases

Frias et al. (2020) assessed the effects of two (closed-door) frequencies (doors opened every 5 or 15 min) and four durations (doors held ajar for 5, 15, 30, or 60 seconds). The average opening sequence was every 10 min for 12 seconds. With that average, results showed that, compared to an open-retail case, energy consumption was 66% lower. Even with the extreme conditions (doors open every 5 min and held ajar for 60 seconds), closed-door cases were 45% lower in energy consumption.

Consumer perception on color

Color appearance is the most important sensory attribute of fresh meat for retail sale according to Djenane et al. (2006). When purchasing meat, the customers judge the quality of the meat by means of color of its surface. The preferred color is a bright red oxymyoglobin which can easily be discolored to brown, which is metmyglobin.(Djenane et al., 2006). This is why being able to extend the shelf life of met is so important. Costumers do not want to buy brown meat, which is how most ground beef gets wasted each year. Carpenter, Cornforth, and Whittier. (2001) in fact conducted a study to evaluate how consumer predilections for beef color affect their eating satisfaction. Panelist thought they were tasting beef product they just evaluated but they were actually given samples of a fresh steak or patty so that taste scores would reflect expectations of the visual they had

previously made. The results showed that consumer preference for beef color was sufficient to impact their probability to purchase (Carpenter, Cornforth, and Whittier., 2001).

Effect of lighting sources on animal product

If meat merchandise looks unpalatable to a consumer, the perception is the product is more than likely unwholesome (Troy and Kerry., 2010). Color, then, is one of the motivating factors in consumer purchasing decisions regarding meat products (Cooper et al., 2016 and Dejenane et al., 2006). Lighting plays an important role in the aesthetic of the product (Wang et al., 2020), but it also aids in the delay of meat spoilage (Djenane et al., 2006).

Color change in ground beef patties

A consumer's perception of freshness and nutritional value is heavily influenced by the color of the red meat on the retail shelf. As research by Schratz and colleagues (2013) examined how consumers' choices for beef color impact their pleasure with their meals Cooper et al. (2016) designed a project to investigate the use of low UV, fluorescent [FLO], light emitting diode [LED], and no light [DRK, negative control]. These lighting sources were used to appraise the effect on color and lipid oxidation of ground beef patties. USDA Select top rounds were ground at 5% fat and 25% fat and made into patties. Each patty was assigned to one of the lighting sources and placed in deli cases at 5^0C. Results concluded that light treatment affected discoloration and metmyoglobin formation in the ground beef patties.

Djenane et al (2006) also studied the effects of UV and found that lighting deprived of UV radiation delayed the meat spoilage as measured by surface color (a* and MetMb percentage), bacterial counts, and sensory assessment (discoloration and odor). Results also

showed that by using either the low UV lamp or the fluorescent with a UV filter extended the shelf life from 12 to 22 to 28 days. Steele et al (2016) also conducted a study with LED and fluorescent lighting. Ground beef, along with other meat animal products, were displayed under LED and fluorescent lighting in two similar, retail display multi-shelf cases with identical operating parameters. Visual and instrumental measuring tools were utilized. Results showed that there was less visual discoloration and cooler internal temperatures in the ground beef under LED lighting.

Lipid oxidation in ground beef patties

Lipid oxidation is a set of free radicals reactions that are highly complex. These reactions are between unsaturated fatty acids and oxygen causing an oxidative degradation of the lipids. This oxidative degradation can cause meat to have a rancidity smell and a lack of bright red color (Ismail., 2008). A study observing the effects of lighting conditions on the retail display life of fresh beef steak sconducted by Djenane et al (2006). The results of this study indicated that light is an important prooxidant in the process of lipid oxidation. In particular within the UV range. The absence of UV radiation caused high protection against photoinduced lipid oxidation. Other studies found that lipid oxidation and pigment oxidation in fresh meat are closely related (Djenane et al., 2006). If there can be a delay in lipid oxidation, there should also be a delay in the discoloration of meat.

As a result of oxymyoglobin oxidation and the formation of metmyoglobin in ground beef can go from a satisfying bright red color to a brownish green color that consumers do not want to buy (Ismail et al., 2008). The irradiation of the product causes this color change as well as foul odor that can occur. A study showed that free radicals

produced by irradiation reacts with the binding sites of myoglobin and form metmyoglobin turning to brown and green color (Ismail et al., 2008).

Irradiation also has a large impact on accelerating the lipid oxidation of meat products (Ismail et al., 2008).This acceleration is due to meat containing 75% or more of water and irradiation of aqueous systems produced hydroxyl radicals, which can initiate oxidative changes in meat. Ismail et al (2008) drafted a study to investigate the color, lipid oxidation and volatiles of irradiated ground beef and found that lipid oxidation of irradiated ground beef increased as aging period and storage times increased. Although this study shows that irradiation plays a role in the deterioration and color change of ground beef which negatively impacts the consumer, irradiation is still the most efficient way to control pathogen in ground beef.

LED lighting

LED lighting is different than normal lighting because the die in the light bulb emits blue light and is coated with phosphorus. That phosphor absorbs a portion of the blue light and re-emits the light as other colors to fill in other parts of the visible spectrum and in turn provides a white light (Schratz et al., 2013). LED lights can emit anywhere from 2,700 K to 7,500 K lighting intensity. Schratz et al., (2013) stated that even compared to the most efficient incumbent technology LEDs are 70% more energy efficient and have higher light efficiency (Schratz et al., 2013). Along with energy efficiency, LED lights also can last over 100,000 operating hours and can last in extreme temperatures (-55 C to +70 C) (Schratz et al., 2013). Unlike traditional light sources (fluorescent), LED lights do not emit ultraviolet light. That UV light is known to attract insects and the heat from the bulb kills the insects. This would be detrimental to any type of refrigerator or retail case with any type of food

inside (Schratz et al., 2013). The UV rays can also damage the packaging on products because it degrades polymers, pigments and dies used.

With energy savings, lower maintenance and life cycle cost, and less heat generation LED lighting could be a positive alternative to fluorescent lighting (Schratz et al., 2013).

LED challenges

Fluorescent lighting is often used in display cases by retailers. According to Cooper et al., (2016) fluorescent illumination, according to this and other studies, may raise the temperature in certain instances, speeding up the process of discoloration. Compared to traditional incandescent bulbs, LED lights are more efficient. The related author Troy and Kerry, (2010), explains that LED lights are less widespread because of the initial expense of case conversion. LEDs now account for just 5% of all US lighting, but by 2035, that number is predicted to rise to 85%, resulting in a 75% reduction in electricity use. Ground beef patties with 5 percent and 25 percent fat were tested in deli cases under low UV fluorescent illumination, LED lighting, or no light at all, according to the results of the study (Carpenter, Cornforth, & Whittier, 2001). Color, myoglobin levels, and lipid oxidation were measured on days 1, 3, 5, and 7 of the experiment.

No matter how bright the lighting was in the display case, the ground beef became increasingly discolored the longer it was there. According to Brenes et al., (2020) retail display days showed that the case with no light had a more appealing red hue than the two other cases. After five days, the LED-lit patties looked better than the fluorescent-lit ones in terms of color retention. Due to availability and demand, Greer and Jeremiah, (1980) expects ground beef to stay in the retail case for fewer than four days. She said that the study's seven-day retail display enabled patties to be examined right up to the conclusion of their shelf life. By the fifth day of a

shop display, you can clearly discern color changes. The amount of fat in the ground beef contributed to the redness, too. On days 1, 3, and 7, independent of light treatment, patties with 25 percent fat were less red than those with 5 percent fat (Stancu, et al., 2016). Because the 25 percent fat patties had less visible lean than the 5 percent fat patties, these outcomes were predicted, according to the authors. Because ground beef with more fat content tends to have less red lean meat composition, it may seem lighter in color to the eye.

LED lights have been shown to reduce labor cost, improve visual perceptions of the consumers, and conserve energy. Retailers use LED color temperature ("cool white" higher 4000 K color temperature) based on aesthetic display of goods; but do they always consider the impairment it could have on the look and quality of the product (Wang et al, 2020).Wang et al (2020) conducted research that measured the effect of varied LED color temperatures on photo-oxidation in 2% fat milk and protection efficiency of packaging with and without light-protective additives. The results were that a combination of appropriate LED color temperature and light-protective additives (LPA) packaging provided a solution for minimizing photo-oxidation in retail dairy cases.Previous research explored numerous ways to improve shelf life, but studies did not combine different retail cases with varying lighting sources. The study also measured the difference in color and lipid oxidation in ground beef patties.

Freezing and Packaging

Freezing meat is way to keep meat from spoiling. Due to competing glycolytic and other oxygen-using reactions being inhibited, frozen food systems are susceptible to liquid oxidation (Guillén-Sans, R., and Guzmán-Chozas, M. 1998). Packaging is an important part of freezing because some packaging materials are able to block oxygen and light reducing the

chances of oxidation, off-flavors, and decreasing TBA values after long time storage (Brewer, M. S., and WU, S. Y. 1993). (Brewer, M. S., and WU, S. Y. 1993) study on the effects of display took ground beef and froze it in the three different types of packaging: vacuum bags, Saran aluminum (SA) wrapped beef or polyvinyl chloride (PVC). After being put on display, the PCV-packaged ground beef had the most intense score for exterior brownness, while the vacuum packaged beef had the least intense exterior brownness score. SA and PVC packaging also had the TBA values that were higher for meat block exterior than meat block interior. The vacuum package showed no change in TBA value due to location which indicated light was not required to initiate lipid peroxidation. It also indicated that a vacuum package is the best way to freeze your meat for long periods of time.

TBARS

The degree of lipid oxidation in meat and processed meat products is often quantified using a thiobarbituric acid reactive substance (TBARS) assay. This assay also provides insight into the shelf-life characteristics and eating quality of beef. (TBARS) are formed as a by-product of lipid peroxidation when the compound 2-Thiobarbituric acid reacts with substances such as ketones, acids, esters, sugars, oxidized proteins, and amino acids. The most common assessment of lipid oxidation in muscle foods is the TBA test for malondialdehyde (MDA) determination. This TBA test involves the reaction between TBA and MDA produced from lipid hydroperoxide decomposition to form a pink complex with maximum absorbance at 532 nm (Guillén-Sans, R., and Guzmán-Chozas, M. 1998).

Material and Methods

Does this paragraph have to stay? Quantitative research a process of collected numerical data that are analyzed using mathematically based methods (in particular statistics) (Creswell, 1994). This study evaluated the impact of retail case type and lighting intensity on ground beef patties from frozen storage. The effects of LED lighting temperature on color and oxidation of previously frozen ground beef patties were also evaluated during this quantitative study.

Data Collection

Coarse ground beef (85% lean) was purchased from a commercial beef processor, fine ground through a 3/8 inch plate, and then formed into 1/3-pound patties with an automatic patty forming machine. Patties will be randomly assigned to four different treatments consisting of open-front or reach-in door display cases and two LED lighting temperatures (3,000 or 3,500 K).

Ground beef will be prepared in 25 lb. batches with 9 patties from each batch being assigned to each treatment combination. No fewer than 4 batches will be prepared per repetition and 4 repetitions will be completed for 16 total batches. One patty will be vacuum packaged and frozen for initial TBARS (rancidity) and hexanal analysis, and 8 patties will be immediately packaged in foam trays with soaker pads and over-wrapped in aerobic PVC film. Four patties will be assigned to TBARS analysis and 4 will be assigned to color evaluation. Patties from individual batches will be evenly dispersed within the cases from top to bottom shelves. Patties will be weighed prior to packaging and after display to determine display losses. Patties for TBARS and hexanal analysis will be removed at days 1, 2, 4 and 7 of display and immediately vacuum packaged and frozen for later analysis.

TBARS

A thiobarbituric acid reactive substances analysis procedure was conducted as designed by Buege and Aust (1978) and as described by Luque et al. (2011) and used to determine the malondialdehyde mg/kg or TBARS value. A stock solution was prepared with TEP and DI water and The ground beef samples were placed in liquid nitrogen and grinded into a powder using a blender. The powder of each patty was weighed out into 10 g samples and placed into a 50 ml centrifuge tube. To set the standard curve, 2 blank tubes were prepared containing 2 mL DI water and 4mL TBA/TCA solution. The blank solutions were first submerged for 15 min in a water bath approximately 100°C, then immediately submerged in an ice water bath for 10 mins, and then settled to an ambient temperature so it can be analyzed as the sample absorption at 531 nm.30 mL of cold deionized water was added to the 50 mL centrifuge tube with the grounded powder sample and vortexed for 30 seconds. The sample was then placed into a centrifuge for 10 mins at 1850xg (3000 rpm). After centrifugation, 2mL of supernatant was carefully pipetted from the sample and placed in a 15 mL centrifuged tube with 4 mL of TCA/TBA reagent and 100 µL BHA solution. The sample was then vortexed, submerged in a hot water bath for 15 minuets and then immediately submerged in an ice water bath for 10 minuets. The samples were centrifuged again at 1850xg (3000 rpm) for 10 min, and the supernatant was transferred to a disposable cuvette for spectrophotometric analysis. Each sampled was analyzed twice at 513 nm absorbance.

In the last step of the autoxidation process, unsaturated oils and fats produce MDA. MDA is a highly reactive compound that is produced by the peroxidation of unsaturated fatty acids. Since the TBA test for MDA determination is a relatively simple procedure, it is

the most frequently used method for the assessment of lipid oxidation in muscle foods (Guillén-Sans, R., and Guzmán-Chozas, M. (1998). Lipid hydroperoxide decomposition produces a reaction between MDA and TBA which can be tested to form a pink complex with a maximum absorbance at 532 nm. For MDA to be released, a heat source and a low pH is needed.

Data Analysis

Data will be analyzed as a completely random design. Pattie will be treated as the experimental unit and blocked by batch. Means will be separated at a level of $P< 0.05$.

Results

Case Style and Light Intensity

There were no interactions observed between the Case*Day, Light*Day, and Case*Light*Day ($P \geq 0.285$). No differences were observed between light treatments, and no differences were observed from case.

Days on Display

It was observed that as the number of days spent in a retail display had an effect on lipid oxidation and color. There is a gradual increase in malondialdehyde levels as the days of being in the retail display also increase (Table 2).This is to be expected because the longer meat is kept in retail display, the longer they are exposed to prooxidants. This means that as oxidations increases, TBARS value also increases.

*Case*Light*

Case*Light is the only interactive effect of significance (P<0.05). It was observed that Closed 3000 had the highest TBARS value (P<.0001), Closed 3500 had the lowest TBARS values (P<.0001), and the Opens were intermediates. A reason for Closed 3000 retail case to have a high TBARS value is due to the unsaturated fatty acids of the ground beef binding to a functional group that caused an increase in malondialdehyde levels.

Conclusions and Discussion

Case Style and Lighting Intensity

There were no interactions recorded between lighting intensities, but previous studies have indicated that not only does LED lighting facilitate colder cases and product temperature than fluorescent light, but it also extends ground beef color life by 0.5 to 1.0 d (Steele et al., 2016). THE same study also tested the effects of LED lighting of ground beef found that although LED lighting extends the color life of meat, it also caused an increase in TBARS value. These results indicate that some LED lighting can also increase oxidation in meat. Other studies indicated that the use of UV lamps had a major effected on fresh beef. A low-UV lamp can significantly extended meat retail life from about 12 d to 22 to 28d. (Djenane et al, 2001).

Although the case styles also had no interactions recorded, previous studies have indicated that enclosed refrigerated display cases were more efficient that open refrigerated display cases. In most categories, there is not a drastic difference between the two retail display cases, but the closed front cases are better for meat products that the open cases. An open retail display case and a display case with a door were used to evaluate how the different environments effected the color of ground beef patties over seven days. The study indicted that patties stored in

the OPEN cases showed a faster decline rate in color variabilities than the patties stored in the DOOR cases (Kutz 2021).

Days of Display

The ground beef patties in this study were effected by the number of days it was kept in a retail case. There is a gradual increase in malondialdehyde levels as the days of being in the retail display also increased. This is to be expected because even in different retail case, the ground beef was still exposed to oxygen causing lipid oxidation to occur and malondialdehyde to be produced. While lipid oxidation is inevitable, different types of packaging and the storage of meat can affect the rate at which the lipid oxidation occurs. (Brewer, M. S., and WU, S. Y. 1993) conducted a study evaluated the TBA values of fresh beef compared to beef that had been frozen for 52 weeks and then displayed in vacuum bags, Saran aluminum (SA) wrapped beef or polyvinyl chloride (PVC). The SA and PVC packaged beef had higher TBA values than the fresh beef. However, the vacuum packaged beef was not different from the fresh beef (Brewer, M. S., and WU, S. Y. 1993). The reason these results are so important is because this information can help dictate which storage preserves the meat longer, but also when and how long meat can stay on a display case and still be bought by a consumer.

*Case*Light*

From the data can conclude that case and light are interactive on one another. By using more specific measurements than just TBARS, further research can be done to figure out what is causing oxidation. To take this research a step further, a study could use volatile compounds instead of TBARS to see which specific groups are driving oxidation. When conducting a study with TBARS, there is always the limiting factor that TBARS can only get a general measurement of all oxidation products. If volatile compounds are used, the results will show which functional

groups are driving oxidation. This includes protein oxidation, lipid oxidation and all products produced by oxidations.

Table 1: Least square means of TBARS Analysis on beef patties from two retail case styles and two light sources.

Treatment	Malondialdehyde mg/kg
Case Style	
Closed Front	0.389
Open Front	0.412
SEM	0.016
P-value	<.0001
Lighting	
3000	0.421
3500	0.380
SEM	0.0017
P-value	<.0001

Note

Table 2: Least square means for Display Days of ground beef for TBARS Analysis

Treatment	Malondialdehyde mg/kg
D0	0.249[e]
D1	0.349[cd]
D2	0.389[cd]
D3	0.339[de]
D4	0.379[cd]
D5	0.440[bc]
D6	0.516[ab]
D7	0.544[a]
SEM	0.03348
P-value	<.0001

[abcd]Least squares means without a common superscript differ (P < 0.05).

Table 3. Least square means of the TBARS Analysis of ground beef patties from the interaction between retail case displays and light sources.

Treatment	Malondialdehyde mg/kg
Case*Light	
Closed Front	
3000	0.438[a]
3500	0.340[b]
Open Front	
3000	0.404[a]
3500	0.420[ab]
SEM	0.02367
P-value	<.0001

[abcd]Least squares means without a common superscript differ (P < 0.05).

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