5-2021

Effects of retail case environment and LED lighting temperature on color of ground beef patties

Mesa Kutz

Mesa Kutz

University of Arkansas

Table of Contents

Introduction. 4

Abstract. 3

Literature Review 6

Materials and Methods. 11

Results 13

Conclusion and Discussion. 14

Tables 16

Literature cited 18

Abstract

The objective of this study was to explore different type of retail cases and case environments, primarily lighting, to quantify the impact on shelf life. Coarse ground 80:20 beef from a local retail establishment was acquired between 7 and 10 d from the box date and fine ground through a 9.5 mm grinder plate, and then formed into 150.25 g patties with an automatic patty forming machine. Each patty was then individually packaged in PVC-overwrap packages and randomly assigned to one of the four different treatments: open, multideck cases with 3000 K lighting **(OPEN3000),** open 3500 K lighting **(OPEN3500),** enclosed, multideck cases with doors with 3000 K lighting **(DOOR3000),** and enclosed, multideck with doors at 3500 K lighting **(DOOR3500).** Patties were displayed for 7 d and instrumental color values (CIE L*, a*, and b*) were taken every 24 h. Data were analyzed as a 2 x 2 factorial arrangement with repeated measures, case type, lighting intensity, and their interaction serving as fixed effects. Patties in DOOR cases possessed greater L* values ($P < 0.05$) than OPEN cases on d 3 of display. A similar trend existed for a*, where DOOR patties were redder ($P < 0.05$) than OPEN patties from d 2 to the end of display. b* values were higher ($P < 0.05$) in DOOR cases from d 1 to d 4 of display. Patties from the DOOR cases also possessed increased chroma values ($P < 0.05$) from d 1 to 6 of display and decreased (indication more red) hue angle values from d 3 to the end of display. No differences were observed between lighting intensity for any trait evaluated ($P \geq 0.293$). These results indicate patties placed in enclosed retail cases with doors are lighter, redder, and more intense in color during display compared to traditional open-front cases, which indicated color stability.

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

Introduction

Background and Need

In the United states, hamburgers have been a long time favorite, and ground beef is a versatile and convenient option for busy consumers (Speer, Brink, & McCully, 2015). Unfortunately, due to the grinding and mixing processes, ground beef also has one of the shortest shelf-life intervals. A short shelf-life means high risk for that product to become spoiled before purchased and, in turn, thrown out or wasted. Globally, nearly 20%-30% of total food volume is discarded (Dreyer, 2018). Extending the shelf-life of ground beef will, not only reduce food waste, but increase the value of beef for all segments of the industry.

Coffin-style and open-front retail display units experience temperature variations. Some products become damaged due to heat penetration from the surrounding ambient environment and some products become damaged because temperature falls below freezing (Kou et al, 2013). 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 (Kou et al, 2013).

Light emitting diode (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 for retail cases has not been determined.

Problem Statement

Food waste is a prominent issue in all sectors of the supply chain and with a growing population, reduction should be a top priority. Roodhuyzen, Luning, Fogliano, and Steenbekkers (2017) stated that, according to the FAO, every year 1.3 billion tons of food produced for human consumption is waisted worldwide. The amount of wasted food is troublesome. Food waste results in both environmental and economic consequences. Environmentally, resources have been used in vain for the production of the food and the landfilling of wasted results in decreased volume for other human solid waste. Economically, there is the cost of food waste itself, but also the associated inefficiencies in the supply chain, upward pressure on prices, and reduced profits (Roodhuyzen, Luning, Fogliano, & Steenbekkers, 2017).

Purpose Statement

In the supply chain food waste occurs at all stages, but in terms of waste prevention, the retail stage has the greatest potential for waste reduction (Dreyer, 2018). The purpose of this research was to explore different type of retail cases and case environments, primarily lighting, to quantify the impact on shelf life. Modifying retail cases and retail case environments may help reduce food waste.

Research Questions

- What are the effects of the type of retail case environments (coffin style and reach-in door style) and lighting (3000 K versus 3500 K lighting temperatures) on the color and oxidation of ground beef patties?
- How can retail case environments **and LED** lighting temperatures be optimized to improve ground beef shelf life?

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.

Literature Review

On a global scale, nearly 24% of food produced for human consumption is wasted (Stancu, Haugaard, & Lahteenmaki, 2016). Previous studies have researched what kind of people waste food, what situations make people waste food, and how to change habits to reduce food waste. From another perspective, research has also been conducted within the supply chain itself to identify sources of waste. There is research looking into packaging to lengthen shelf life and adding certain preservatives to lengthen shelf life. Few researchers have studied using different lighting sources and retail display cases to lengthen shelf life and, in turn, reduce the food 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), maintaining desirable appearance of retail meats (Greer & Jeremiah, 1980), reducing energy cost (Frias et al., 2020), and reducing food waste (Brenes et al., 2020).

Temperature variation within retail display cases

The FDA Food Code threshold temperature for highly perishable food is 5 degrees Celsius (Frias et al, 2020) and it is recommended that display cases maintain meats at internal temperatures from 2 to 4 degrees Celsius (Greer & Jeremiah., 1980). Greer & Jeremiah., (1980) conducted a study looking into the effect proper control of retail case temperature has on improving beef shelf life. Thirty-five wholesale beef ribs were aged for six days and frozen at -20 C. Fifty rib eye steaks were cut before the experiment and wrapped in oxygen-permeable polyvinyl film. Steaks were placed randomly into five different display case blower temperatures and were measured for 4 days of retail display and blower temperatures were recorded 13 times daily. Steaks were evaluated by a 3-member sensory paned for discoloration and retail acceptability. Results show that steak surface temperature averaged about 9 C higher than that of the incoming blower air and in turn resulting in lower bacterial generation time (by 0.7 hours) and more than half a day reduction in steak shelf life. Greer & 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 results could be continued to show the variation in both open-door and closed-door retail cases.

Brenes et al. (2020) also conducted a study that found temperature variation can be minimized with closed-door retail cases. Twenty-five open and closed refrigerated display cases in ten retail stores in five states were monitored for temperature and humidity over nine months. Data were recorded at multiple positions within the retail cases. Not only was there a significant difference in temperature in open- and closed- retail cases, but also a significant difference based on product position within the case. The open-door cases and the top front position in the case both had the highest recorded temperatures. To ensure that product stayed below the threshold, it was been found that closed-door retail cases trap the temperature in and result in less variation.

Efficiency within retail display cases

Frias et al. (2020) evaluated 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.

Effect of color on consumer perception

In a retail environment the average consumer bases their whole judgment of freshness and wholesomeness on the color of the red meat product (Troy & Kerry. 2010). Carpenter, Cornforth, and Whittier. (2001) actually conducted a study to evaluate how consumer preferences for beef color affect their eating satisfaction. Three single streaks from a single short loin and groups of four patties of freshly ground beef were packaged in different modified atmospheres to promote development of red, purple, and brown colors. A consumer panel described the color, indicated their liking of the appearance, and indicated their likelihood to purchase similar meat. The panelist then tasted what they thought was the beef product they just evaluated but 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 influence their likelihood to purchase (Carpenter, Cornforth, and Whittier., 2001).

Effect of lighting sources on animal product

If a product looks unappetizing to a consumer, the perception is the product is unwholesome (Troy & 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). Not only does lighting play a role in the aesthetic of the product (Wang et al., 2020), but it also delays meat spoilage (Djenane et al., 2006).

Color change in ground beef patties

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 evaluate the impact 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 showed that light treatment affected discoloration and metmyoglobin formation in the ground beef patties. Djenane et al (2006) also found that lighting without UV radiation delayed meat spoilage as assessed by surface color (a* and MetMb percentage), bacterial counts, and sensory evaluation (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 multi-shelf, retail display cases with identical operating parameters. Visual and instrumental measuring tools were used. Results showed that there was less visual discoloration and colder internal temperatures in the ground beef under LED lighting.

Lipid oxidation in ground beef patties

Djenane et al (2006) conducted a study looking into the effects of lighting conditions on the retail display life of fresh beef steaks. Results showed that the absence of UV radiation resulted in high protection against photoinduced lipid oxidation. Other studies found that lipid oxidation and pigment oxidation in fresh meat go hand in hand (Djenane et al., 2006). In turn, delaying lipid oxidation should result in the delay of meat discolorations.

As a result of oxymyoglobin oxidation and the formation of metmyoglobin ground beef can go from a satisfying bright red color to an unappetizing brown color (Ismail et al., 2008).

This happens because of the irradiation of the product. Research had been done that suggests that free radicals produced by irradiation can react with the binging sites of myglobin 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). 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. This work has shown that irradiation plays a role in the visual appearance and deterioration of ground beef which negatively impact the consumer. However, the best method for pathogen control in ground beef is irradiation. That being said, more research needs to be done on alternative ways to reduce lipid oxidation in ground beef patties.

LED lighting

LED lighting is different than normal lighting because the die in the light bulb emits blue light and is coated with phosphor. 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) states 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

LED lights conserve energy, save labor, and enhance visual perceptions of the consumers. Retailers use LED color temperature ("cool white" higher 4000 K color temperature) based on aesthetic display of products, but they do not always consider the damage it could have on the look and quality of the product (Wang et al, 2020). Wang et al (2020) conducted a study 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. Results indicated 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.

Prior research explored various ways to improve shelf life, but studies did not combine different retail cases with varying lighting sources and then measure the difference in color and lipid oxidation in ground beef patties. Studying the environment at a consumer purchasing level will allow us to potentially impact one of the biggest areas within the supply chain with regards to food waste.

Material and Methods

During this study quantitative data was used to investigate the effects of the retail case environments and a variety of lighting temperatures on color and oxidation of ground beef patties. This study followed a strict, carefully designed study to ensure integrity and strengthen rigor. This study aimed to produce knowledge that can improve shelf life.

Research Design

This study was conducted using a quantitative, true experimental design approach. Quantitative research explains a phenomena by collecting numerical data that are analyzed using mathematically based methods (in particular statistics) (Creswell, 1994). In this design instrumental color (L*, a*, b* and reflectance from 400 to 700 nm) were measured and collected on ground beef patties. For one replication: four, 11.34 kg, batches were prepared, and 4 replications were completed for 16 total batches. Patties were treated as the experimental unit and blocked by batch.

Rigor

Utilizing the true experimental design by nature strengthens rigor. Williams (2007) stated that true experimental design provides a higher degree of control in the experiment and produces a higher degree of validity. In this experimental protocol, which was guided by a meat scientist, packaged coarse ground beef was collected from a commercial beef processor and immediately brought to the University of Arkansas Meat Abattoir. Ground beef was processed between 7 and 10 days from the box date. Patties were made by the Hollymatic Corporation (Countryside, IL) automatic patty machine. All patties were made to the same size and thickness. Labels were made for the packaging. Those labels were randomly assigned to random patties throughout processing of the patties. Treatments were assigned to the patties. Once patties were packaged and labeled, they were immediate brought to the University of Arkansas Retail Display lab. All data collection used the same instruments and was collected at the same time every day. Each repetition collected data for the same amount of days.

Data Collection

Coarse ground 80:20 beef was fine ground through a 9.5 mm grinder plate, and then formed into 150.25 g patties with an automatic patty forming machine. Each patty was randomly assigned into one of the four different treatments: Hill Phoenix open, multideck case (Colonial Heights, VA) with 3000 K lighting **(OPEN3000)**, open, multideck case with 3500 K lighting **(OPEN3500)**, Hill Phoenix enclosed, multideck case with doors (Colonial Heights, VA) with 3000 K **(DOOR3000)**, and enclosed, multideck case with doors with 3500 K **(DOOR3500)**. Individually, four patties were immediately packaged and put in foam trays with soaker pads and over-wrapped in aerobic PVC film. Patties were assigned to color evaluation. Patties from individual batches were evenly dispersed within the cases from the top to the bottom shelves. Prior to data collection all instruments were standardized. Instrumental color (L*, a*, b* and reflectance from 400 to 700 nm) was measured in triplicate with the Hunter Lab MiniScan EZ spectrophotometer (Reston, VA) every 24 hours for 7 days of retail display. Three measurements were averaged. Patties were rotated every 24 hours after collection.

Data Analysis

Data were analyzed as a 2 X 2 factorial arrangement with repeated measures, case type, lighting intensity, and their interaction serving as fixed effects. Patties were treated as the experimental unit and blocked by batch. Means were separated at a level of $P < 0.05$.

Results

Lighting Intensity

No interactions were observed between lighting intensity for any trait evaluated ($P \geq$ 0.293) No difference in any instrumental color was observed.

Case Style

The color variabilities measured (L*, a*, b*, Chroma) after day 0 of retail display, declined (P<0.05) and continued to decline (P< 0.05) until d 7 for both OPEN and DOOR cases, except patties in OPEN started to increase in L* values (P< 0.05) after d 5 (Table 1). Increased (indication of less red) hue angle values were measured from d 0 to end of display for both OPEN and DOOR cases (Table 1). However, patties in OPEN cases declined at a faster rate compared to patties in DOOR cases in color variabilities measured (L*, a*, b*, Chroma) (Table 1). Patties in OPEN case also increased at a faster rate in hue angle measurement (Table 1). Results from the case styles are present in Table 2. Patties in DOOR cases possessed greater L* values ($P< 0.05$) than OPEN cases on d 3 of display. A similar trend existed for a*, where DOOR patties were redder ($P< 0.05$) than OPEN patties from d 2 to the end of display. b* values were higher ($P< 0.05$) in DOOR cases from d 1 to d 4 of display. Patties from the DOOR cases also possessed increased chroma values ($P< 0.05$) from d 1 to 6 of display and decreased (indication more red) hue angle values from d 3 to the end of display.

Conclusions and Discussion

Lighting Intensity

Although the results show no interactions between lighting intensities, previous work has indicated that using low-ultraviolet (UV) lamp significantly extended meat retail life from about 12 d to 22 to 28 d (Djenane et al, 2001). Other work states that under LED lighting beef products, including ground beef, showed less ($P< 0.05$) visual discoloration. Both of these studies conclude that low UV light or LED lighting are major contributors to extending shelf life. Martinez et al., (2006) also did a study with lighting intensities. They found that the most noticeable result was the fact that during the first 8 days of storage sausage samples that were displayed in the dark showed no significant difference ($P < 0.05$) to sausage samples displayed under UV radiation-free lighting (Martinez et al., 2006). Further studies should focus on including LED lighting compared to different fluorescent lighting temperatures.

Case Styles

Similar to these results, previous literature indicates that all color variables measured after 24 h of retail display decline (*P*< 0.05) as storage length increased (Martin et al., 2013). However, the results show OPEN cases had an increase in the L* value (*P*< 0.05) after d 5. Results indicate patties placed in enclosed retail cases with doors are lighter, redder, and more intense in color during display compared to traditional open-fronted cases, which indicated greater color stability.

Table 1. Interaction of retail case type and display day on instrumental color values of beef patties.

Treatment	L*	a*	b*	Chroma	Hue Angle
Door					
0	56.12^{a}	30.94^{a}	25.18^{a}	39.90^{a}	39.11^{l}
1	55.10^{b}	26.00^{b}	22.39^{c}	34.34^{b}	40.67^{k}
2	54.51^{cde}	23.38^{c}	20.94^{e}	31.41^{d}	41.84^{j}
3	54.16^{de}	21.62^{e}	20.18^{f}	29.59^{f}	42.99^{i}
4	54.02^{def}	20.02^{g}	19.57^{h}	27.99^{h}	44.29^{h}
5	54.07^{def}	17.44^{i}	18.75^{i}	25.61^{j}	47.03^{f}
6	54.60^{bcd}	13.93^{k}	17.90^{jk}	22.72^{l}	52.16^{d}
7	54.72^{bc}	11.68^{m}	17.83^{j}	21.40^{n}	57.15^{b}
Open					
0	56.39^{a}	31.15^{a}	25.16^{a}	40.00^{a}	38.64^{l}
1	54.62^{bcd}	25.71^{b}	22.18^{b}	33.98^{c}	40.73^{k}
2	53.95^{ef}	22.82^{d}	20.76^{d}	30.88^{e}	42.28^{j}
3	53.38^{g}	20.98^{f}	20.09^{f}	29.08^{g}	43.82^{h}
4	53.55^{fg}	18.94^{h}	19.30^{g}	27.07^{i}	45.69^{g}
5	53.49^{fg}	15.89^{j}	18.57^{i}	24.48^{k}	49.60^{e}
6	54.28^{cde}	12.57^{l}	18.04^{k}	22.02^{m}	55.12^{c}
7	54.23^{cde}	11.25^{n}	18.35^{l}	21.55^{n}	58.76^{a}

^{ab}Least squares means, within the same main effect, without a common superscript differ ($P < 0.05$).

Table 2. Least square means of instrumental color values from beef patties from two light sources and two retail case types.

Treatment	L*	a*	b*	Chroma	Hue Angle
Case Style					
Door	54.6665	20.6326[a]	20.3470	29.1146[a]	45.6600[b]
Open	54.2424	19.9197[b]	20.3125	28.6337[b]	46.8319[a]
P value	0.0523	<0.0001	0.3570	<0.0001	<0.0001
Lighting					
3000	54.4627	20.3020	20.3101	28.8778	46.1769
3500	54.4463	20.2504	20.3495	28.8705	46.3151
P value	0.9396	0.5659	0.2933	0.9194	0.4112

[ab]Least squares means, within the same main effect, without a common superscript differ ($P < 0.05$).

References

Atilio de Frias, J., Luo, Y., Zhou, B., Zhang, B., Ingram, D.T., Vorst, K., Brecht, J.K., Stommel, J. (2020) Effect of door opening frequency and duration of an enclosed refrigerated display case on product temperatures and energy consumption. *Food Control,* 111, 107044

Brenes, A.L.M., Brown, W., Steinmaus, S., Brecht, J.K., Xie, Y., Bornhorst, E.R., Luo, Y., Zhou, B., Shaw, A., Vorst, K. (2020). Temperature profiling of open- and closed- doored produce cases in retail grocery stores. *Food Control,* 113, 107158.

Carpenter, C.E., Cornforth, D.P., Whittier, D. (2001). Consumer preferences for beef color and packaging did not affect eating satisfaction. *Meat Science,* 57(4), 359-363

Cooper, J.V., Wiegand B.R., Koc, A.B., Schumacher, L., Grun, I., Lorenzen C.L. (2016). RAPID COMMUNICATION: Impact of contemporary light sources on oxidation of fresh ground beef. *Journal of Animal Science,* 94(10), 4457-4462.

Creswell, J.W., Research Design: Qualitative & Quantitative Approaches, London: SAGE Publications, 1994.

Djenane, D., Sanchez-Ezcalante, A., Beltran J.A., Roncales, P. (2006). Extension of the Retail Display Life of Fresh Beef Packaged in Modified Atmosphere by Varying Lighting Conditions, *Journal of Food Science,* 66(1)

Dreyer, H. C. D., Popovska, I. D. P., Yu, Q. U., Hedensterna, C. P. H. (2019). A ranking method for prioritizing retail store food waste based on monetary and environmental impacts. *Journal of Cleaner Production, Volume 210,* page 505-517.

Greer, G.G., Jeremiah, E. (1980). Proper Control of Retail Case Temperature Improves Beef Shelf Life. *Journal of Food Protection,* 44(4), 297-299

Ismail, H. A., Lee, E. J., Ko, K.Y., Ahn, D. U. (2008). Effects of aging time and natural antioxidants in the color, lipid oxidation and volatiles of irradiated ground beef. *Meat Science*, 80(3), 582-591. Retrieved on September 30, 2020 URL

Kou, L. P., Luo, Y. L., Ingram, D. T. I., Yan, Y. S., Jurick, W. M. J. II. (2015). Open-refrigerated retail display case temperature profile and its impact on product quality and microbiota of stored baby spinach. *Food Control, Volume 47,* page 686-692.

Martin, J.N., Brooks J.C., Brooks T.A., Legako J.F., Starkly J.D., Jackson S.P., Miller M.F. (2013) Storage length, storage temperature, and lean formulation influence the shelf-life and stability of traditionally packaged ground beef. *Meat Science,* 95(3), 495-502

Martinez, L., Cilla, I., Beltran J.A., Roncales, P. (2006). Effect of illumination on the display life of fresh pork sausages packaged in modified atomosphere. Influence of the addition of rosemary, ascorbic acid and black pepper. *Meat Science,* 75(3), 443-450.

Roodhyzen, D.M.A.R., Luning, P.A.L., Fogliano, V.F., Steenbekkers, L.P.A.S. (2017). Putting together the puzzle of consumer food waste: Towards an intergral perspective. *Trends in Food Science & Technology, Volume 68,* Page 37-50.

Schratz, M., Gupta, C., Struhs, T.J., Gray, K. (2013). Reducing energy and maintaining costs while improving light quality and reliability with LED lighting technology. *Annual IEEE Pulp and Paper Industry Technical Conference (PPIC),* pp. 43-49, doi: 10.1109/PPIC.2013.6656043.

Speer, N. S., Brink, T. B., McCully, M. M. (2015). Changes in the Ground Beef Market and What it Means for Cattle Producers.

Stancu, V., Haugaard, P., Lahteenmaki, Liisa. (2016). Determinants of consumer food waste behavior: Two routes to food waste. *Appetite,* 96, 7-17

Steele, K.S., Weber, M.J., Boyle, E. A. E., Hunt, M.C., Lobaton-Sulabo, A.S., Hiebert, Y.H., Abrolat, K.a., Attey, J.M., Clark, S.D., Johnson, D.E., Roenbaugh, T.L. (2016). Shelf life of fresh meat products under LED or fluorescent lighting. *Meat Science,* 117, 75-84. Retrieved on September 30, 2020 URL

Sukamolson, S. (2007) Fundamentals of quantitative research.

Troy, D.J., Kerry, J.P. (2010). Consumer perception and the role of science in the meat industry. *Meat Science,* 86, 214-226.

Wang, A., Duncan, S.E., Whalley, N.W., O'Keefe, S.F. (2020). Interaction effect of LED color temperatures and light-protective additive packaging on photo-oxidation in milk displayed in retail dairy case. *Food Chemistry,* 323, 126699. Retrieved on September 30, 2020 URL

Williams, C. (2007). Research Methods. *Journal of Business & Economic Research,* 3(5).