The Consumer Cold Chain: Evaluation of Consumer Handling Behaviors on Fresh Beef Products at Retail Locations and during Vehicular Transport from Retail to Residence and the Implications on Palatability

by

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ABSTRACT

Unlike the controlled and highly regulated systematic steps in the production and handling of the fresh red meat products prior to purchase, a consumer's handling behavior cannot be regulated by an outside authority after the product has reached a consumer's hands. The objective of this research was to gain a greater understanding of consumer handling behavior during transport from retail to residence and impactions on fresh beef temperature, color, and palatability. According to survey research, there is a 91.8 % chance fresh red meat could be transported without temperature protection. Consumers will commonly leave fresh beef products in a cart up to 20 minutes prior to check-out, can take up to 60 minutes to return home, and will run other errands with fresh red meat products left in the vehicle. Upon removal from the retail display case and placement in cart, the average time needed to exceed a safe internal temperature of 4.4 °C in over-wrap packaged ground beef was 49 minutes given the retail environmental temperature of 21.2 °C. Moreover, after 120 minutes, an internal temperature of 9.0 °C was observed. Regardless of air conditioning, the inside of a vehicle can exceed 37.7°C given an environmental temperature of 32.2 °C. Fresh red meat can exceed 4.4 °C during vehicular transport from retail to residence especially in the absence of air conditioning and after stopping for additional errands. A cooler bag without ice can exceed 38.5 °C inside the bag, while the addition of ice results in a mean temperature of 6.3 °C when environmental temperatures exceed 32.2 °C. Finally, handling behavior in retail and during vehicular transport that results in temperature abuse will directly impact fresh red meat color appeal and palatability ($P < 0.05$).

Results indicate the need for consumer awareness and proper behaviors that will mitigate temperature abuse.

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"I believe that this is a practical world and that I can count only on what I earn. Therefore, I believe in work, hard work. I believe in education, which gives me the knowledge to work wisely and trains my mind and my hands to work skillfully. I believe in honesty and truthfulness, without which I cannot win the respect and confidence of my fellow men. I believe in a sound mind, in a sound body and a spirit that is not afraid, and in clean sports that develop these qualities. I believe in obedience to law because it protects the rights of all. I believe in the human touch, which cultivates sympathy with my fellow men and mutual helpfulness and brings happiness for all. I believe in my Country, because it is a land of freedom and because it is my own home, and that I can best serve that country by "doing justly, loving mercy, and walking humbly with my God." And because Auburn men and women believe in these things, I believe in Auburn and love it." -George Petrie (1943)

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ever be able to thank you for everything you have done. But I promise; I will never stop trying. I love you forever and always!

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LIST OF ABBREVIATIONS

CDC	Centers for Disease Control
DFD	Dark, Firm, and Dry
ERS	Economic Research Service
FDA	Food and Drug Administration
FSIS	Food Safety Inspection Service
LAB	Lactic Acid Bacteria
MDA	Malondialdehyde
NBQA	National Beef Quality Audit
TBARS	Thiobarbituric Acid Reactive Substances
TTF	Time to Failure
USDA	United States Department of Agriculture

Chapter I: Review of Literature

Introduction

In the United States, 3,000 pounds of food is wasted every second. Of that, 12 % of food waste is meat, which equates to 21,600 pounds of meat per minute or 1,296,000 pounds of meat per hour (Morgan, 2012). Potentially, 925 live fed steers or an excess of 1,469 dressed beef carcasses is wasted in the United States in an hour. The United States Department of Agriculture's Economic Research Service (USDA-ERS) estimates 31 % of food loss occurs at the retail and consumer levels, corresponding to over 161 billion dollars' worth of food (USDA-OCE, 2016). Food is wasted due to misbranding, not meeting specifications, expired shelf-life, consumer confusion of packaging dates, lack of accountability or audits, too much emphasis placed on aesthetics, and most notably, improper consumer handling behavior (USDA-OCE, 2016; Gunders, 2012). Handling behavior is described as any product contact point.

Temperature abuse is a negative handling behavior and can occur at any point in-time along the cold chain, including retail, transport to residence, storage, and handling. Temperature abuse is defined as risky handling behavior when a meat product is in an environment exceeding 4.4 ℃, but less than 60.0 ℃, for any allotment of time (USDA-FSIS, 2013). An estimated 93 % of individuals do not use a cooler or temperature protection when transporting temperature-dependent food from retail to residence (Godwin and Copings, 2005). Likewise, 92 % of individuals will make stops at other locations with temperature dependent food products in the vehicle with 63 % of individuals visiting two or more additional retail locations (Godwin and Copings, 2005). A refrigeration temperature over 4.4 ℃ can lead to unsafe storage conditions as well as spoilage for fresh meat products; notably, at residence, approximately 28 % of in-home refrigeration temperatures will exceed 4.4 °C; (Kosa et al., 2007). Spoilage is detrimental to meat palatability and a positive eating quality experience.

Palatability is important to the consumer (O'Quinn et al., 2016; Corbin et al., 2015; Huff-Lonergan and Lonergan, 2005; Boleman et al., 1997; Huffman et al., 1996; Miller et al., 1995). Meat palatability is defined as palate sensory experience resulting from perceived tenderness, juiciness, and flavor. A consumer's first perception of eating quality is with their eyes, followed by smell, and lastly by taste. Purchase is typically driven by color, followed by visible fat, price, and retail-cut type; alternatively, satisfaction is primarily driven by tenderness, followed by juiciness, and finally, overall flavor (Robbins et al., 2003). Notably, given the primary constituents and ultimate chemical nature of lean muscle and fresh meat, meat is extremely volatile in regards to palatability due to intrinsic and extrinsic reactions with the environment.

Food Waste

Food Waste in the United States

Improper consumer handling behaviors ultimately lead to food waste and reduced sustainability both domestically and globally. Annual food waste has increased over 50 % since the 1970's. In the United States, 3,000 pounds of food is wasted every second. Of that, 12 % of food waste is meat, which equates to 21,600 pounds of meat wasted per minute or 1,296,000 pounds of meat per hour (Morgan, 2012). Given the aforementioned percentage and pounds of meat waste, this is equivalent to, 925 live fed steers or an excess of 1,469 dressed beef carcasses wasted in the United States in an hour. On a global scale 1.3 billion tons of food or one-third of total annual food produced will be wasted or lost each year (Morgan, 2012). The United States Department of Agriculture estimates 31 % of food loss occurs at the retail and consumer levels, corresponding to over 161 billion dollars' worth of food (USDA-OCE, 2016). Food waste is the single largest component going into municipal landfills (USDA-OCE, 2016).

Reducing Food Waste

Food is wasted due to misbranding, not meeting specifications, expired shelf-life, improper consumer handling behavior, consumer confusion of packaging dates, lack of accountability or audits, and too much emphasis placed on aesthetics (USDA-OCE, 2016; Gunders, 2012). Potential remedies at the retail level include: identify opportunities to reduce overhead and product volume, discount offerings for out-of-date or slightly damaged goods, product display redesign using platforms and other props to make produce bins appear more full, increased donations to community services, and allowing prepared foods to run out near closing time or more repurposing of foods (Gunders, 2012). Likewise at the household-level, remedies include meal planning, creating food lists that are followed, education on food quality and expiration dates, better use of freezing to preserve food before spoilage, and preparation of smaller portions in homes where leftovers are not routinely consumed (Gunders, 2012).

Consumer Studies and University Extension

The Consumer

Demographic characteristics of a risky consumer population most likely to commit temperature abuse to a meat product are as follows: 1) male, 2) Caucasian ethnicity, 3) between the ages of 30 and 54, 4) greater than a high school education, 5) resides in a metro area (Cates, 2007; Patil et al., 2005). Additionally, individuals who live alone are more likely to exhibit 'risky' food handling behaviors (Cates, 2007).

Consumer Survey

A survey related to consumer behavior from "Grocer to Home" was developed, implemented, and analyzed by Godwin and Copings, and subsequently published in 2005. Godwin and Copings (2005) interviewed (n = 551 in Phase 1, n = 200 of the original 551 in Phase 2) individuals from six different states over two phases in order to assess how the respondents purchase, transport, store, and otherwise handle food. The Phase 1 questionnaire covered constructs related to purchase and transport; and Phase 2 assessed in-home handling and refrigeration conditions.

Godwin and Coppings (2005) revealed the majority of respondents, 44 %, go grocery shopping at least once a week. Furthermore, the study revealed 82 % of respondents return-home in 20 minutes or less with 51 % returning-home in 10 minutes or less; importantly, 9 % of individuals took from 30 minutes to over an hour to return-home (Godwin and Coppings, 2005). Related to food shopping, Godwin and Coppings (2005) reported only 8 % of respondents immediately return to residence with temperature dependent food items in the vehicle, 63 % of respondents admitted to going to more than one store while running additional errands. In the face-to-face survey respondents did not evidence concern of when or where the cold reliant food items were placed in the designated shopping cart; much less how the product was bagged for transport or when the product would be placed in the refrigerator. Godwin and Copings (2005) revealed 52 % of food products are placed in the trunk of the vehicle, followed by the seat, and "in any/all depending on the amount"; 28 % and 25 %, respectively. Only 7 % of respondents admitted to using a cooler to protect cold food items. Furthermore, Godwin and Copings (2005) found consumers do not know the actual temperature of their refrigerator or freezer, and the majority of the respondents admitted to only adjusting the 'temperature dial' in the refrigerator once a year. Regarding food- storage, 94 % of respondents keep fresh meat products, both whole-muscle and non-intact products frozen. Furthermore, delicatessen and ready-to-eat meat products were typically stored in the refrigerator. Lastly, Godwin and Copings (2005) found consumers place meat products on the top-shelf of the refrigerator, and often-times have open containers or ready-to-eat products stored directly next-to raw meat products.

University Extension Systems and Recommendations

Extension literature written with the consumer as the audience is primarily focused on safe in-home food handling and preparation (Boyer and McKinney, 2013; Weddle-Schott, 2007; Kilonzo-Nthenge et al., 2006; Burney, n.d.). Beginning at the retail-level, Boyer and Mckinney (2013) recommend customers purchase meat products before the 'sell by date' in order to provide 'safe and nutritious' food for consumers. Additionally, Boyer and McKinney instruct individuals to select and pick-up refrigerated and frozen foods immediately prior to checkout since refrigerated foods should be cold, and frozen foods should be solid with no evidence of thawing (Boyer and Mckinney, 2013; Kilonzo-Nthenge et al., 2006). Next, refrigerated and frozen food should be bagged together to assist in symbiotic temperature preservation. It is recommended to drive straight home with perishables placed inside the vehicle and kept on ice (Boyer and Mckinney, 2013; Kilonzo-Nthenge et al., 2006). Upon arriving at residence, perishables, first and foremost, should be immediately taken from the vehicle and placed in refrigeration. During storage, extension literature recommends keeping meat out of the danger zone; specifically between the temperatures of 4.4 °C and 60 °C (Boyer and McKinney, 2013; Weddle-Schott, 2007; Kilonzo-Nthenge et al., 2006; Burney, n.d.).

Consumer Handling Behaviors

Food Handling

The reduction of cross contamination is imperative to safe food handling environments. As reported by Cates (2007) 47 % of consumers do not sanitize or wash their hands prior to handling raw meat; and 35 % of consumers do not sanitize or wash their hands after handling raw meat. This practice can quickly spread pathogens around a food prep area. Likewise, food contact surfaces such as knives and cutting boards can spread pathogens from one food product to the next if not cleaned and sanitized properly. This research revealed that approximately one-quarter of consumers does not thoroughly sanitize food contact surfaces (Cates, 2007).

Upon removal from a freezer, prior to cooking, meat is typically thawed for cooking efficiency and palatability improvement (Hergenreder et al., 2013; Obuz and Dikeman, 2003). Thawing methods prior to cooking include: 1) in the refrigerator, 2) in cold water, and 3) using a microwave. Research by Manios and Skandamis (2015) reported that meat thawed on a counter-top had significantly higher pathogen counts and logarithmic growth when compared to meat thawed in a refrigerator or microwave due to the amount of time the product was held above 4.4 °C but below 60 °C. Established research by Obuz and Dikeman (2003) revealed frozen steaks take a longer period of time to cook, and have a higher percentage of cook loss; four additional minutes to reach desired endpoint temperature and a six % cook loss increase, respectively. Research by Hergenreder et al. (2013) suggested the faster a meat product is thawed, purge and total moisture loss increase leading to a less juicy meat product.

Cookery

Cookery is considered a consumer-implemented food safety hurdle due to the inability of microorganisms to survive a proper heat treatment and subsequent logarithmic reductions

(Marriott and Gravani, 2006). Microbial contamination of raw meat products can be a problem; nonetheless, most cases of foodborne illness can be prevented with proper cooking, including adequate temperatures, or processing of food to destroy pathogens (USDA-FSIS, 2013; Weddle-Schott, 2007). Safe minimum internal temperatures for meat products, per the United States Department of Agriculture – Food Safety Inspection Service (USDA-FSIS, 2015), are presented in Appendix A. Internal color cannot accurately determine temperature; thus, it is not safe to use the color of beef as an indicator of safety (Weddle-Schott, 2007; Romans et al., 2001). The only way to ensure that a safe minimum internal temperature has been reached is to use a thermometer. Regardless of established and published minimum temperature thresholds for meat products, consumers are unable to accurately verify internal temperature, since only 31 % of consumers actually use a food thermometer (Cates, 2007). Additionally, 35 % of consumers do not thoroughly re-reheat meat products (Cates, 2007).

The Cold Chain

Cold Chain Overview

The sequence of events from production animal harvest to a consumer's plate is quite complex and important as evidenced by the $992 billion agricultural contribution to the United States gross domestic product (USDA-ERS, 2017). Without a doubt, the sequence of events involves multiple players in the animal and meat industry. The packer, processor, and retail location are most notably involved in the cold chain. The cold chain involves controlled and highly regulated systematic steps in the production, handling, and logistics of fresh red meat products prior to purchase. Cold chain maintenance, avoidance of fluctuations or temperature abuse during handling and transportation are crucial for the quality of meat (Pothakos et al., 2015; Säde, 2011; Nychas et al., 2008).

Food Code Provisions

The purpose of the Food and Drug Administration's (FDA) model food code is to: "assist food control jurisdictions at all levels of government by providing them with a scientifically sound technical and legal basis for regulating the retail segment of the food industry it represents" (FDA, 2013). As noted by the FDA (2013); "although not federal requirements, the model Food Code provisions are designed to be consistent with federal food laws and regulations, and are written for ease of legal adoption at all levels of government". The retail-level guidance is imperative since the primary goal of the model is to ensure that food at retail is safe and properly protected and presented.

Time and Temperature Guidance

As recommended by the FDA in Chapter 3 - Section 501.12 of the Food Code (2013) titled "Time/Temperature Control for Safety Food, Slacking" food should be: A) Under refrigeration that maintains the food temperature at 5 °C or less; or B) At any temperature if the food remains frozen. Additionally, in Chapter 3- Section 501.19 of the Food Code (2013), the FDA specifies if time without temperature control is used as the public health control up to a maximum of 4 hours, the food shall have an initial temperature of 5 °C or less when removed from cold holding temperature control, or 57 °C or greater when removed from hot holding temperature control. Alternatively, if time without temperature control is used as the public health control up to a maximum of 6 hours, the food shall have an initial temperature of 5 °C or less when removed from temperature control and the food temperature may not exceed 21 °C within a maximum time period of 6 hours, or the food shall be monitored to ensure the warmest portion of the food does not exceed 21 °C during the 6 hour period. During storage (Chapter 3-Section 303.12), packaged meat products: “may not be stored in direct contact with ice or water if the food is subject to the entry of water because of the nature of its packaging, wrapping, or container or its positioning in the ice or water” due to the possibility of cross-contamination (FDA, 2013). Lastly, during thawing (Chapter 3- Section 501.13) food shall be under refrigeration that maintains the food temperature at 5 °C. Otherwise, food shall be completely submerged under running water at a water temperature of 21 °C or below with sufficient water velocity to agitate and float off loose particles in an overflow for a period of time that does not allow thawed portions of ready-to-eat food to rise above 5 °C or for a period of time that does not allow thawed portions of a raw animal food requiring cooking to be above 5 °C for more than 4 hours.

Food Safety

Food Safety Overview

Food safety and public health is an important priority in the United States. The Centers for Disease Control and Prevention (CDC) (2016) estimates that each year roughly 1 in 6 Americans; 48 million people, respectively, will become sick resulting in 128,000 hospitalizations and 3,000 deaths due to foodborne diseases, infections, and poisoning. Contamination that can lead to foodborne illness can occur at any point from pasture to plate. This can be cause by lapses in the production chain, cold chain, or consumer handling. The rate of microbial proliferation and thermal death time is due to a combination of extrinsic and intrinsic factors including temperature, oxygen availability, relative humidity, water activity, pH, oxidation-reduction potential, nutrient requirements, and inhibitory substances (Marriott and Gravani, 2006). Given the aforementioned intrinsic and extrinsic factors related to microbial proliferation, meat is an ideal growth media due to nutrients and applied storage conditions.

Microbes can achieve optimal growth at temperatures below 20 °C (psychrotrophs), between 20 °C and 45 °C (mesophiles), and above 45 °C (thermophiles). The optimal temperature for microbial proliferation is from 14 °C to 40 °C (Marriott and Gravani, 2006). Research and consumer surveys have revealed that at some point in time during the cold chain; both in industry and consumer-cold chains, a meat product will be in an unacceptable temperature range for a given bacteria inducing logarithmic growth and product degradation and food safety concerns (Cates, 2007; Godwin and Copings, 2005). Since cooking is one of the last food safety hurdles at the household-level, heat shock and heat resistance become a concern since microbial cells are exposed to stresses which may lead to reversible or non-reversible mechanical injuries (Weddle-Schott, 2007).

Heat Shock and Associated Pathogens

Heat shock can be defined as the subjection to high temperatures prior to actual thermal processing or cooking. As cited by Farber and Brown (1990) in reference to historical work by Lindquist (1986) and Craig (1985), the induction heat shock protein synthesis occurs in microorganisms exposed to sub-lethal temperatures for a period of time; and ultimately, the heat shock response by the organism results in an increased resistance to a subsequent lethal heat treatment. This heat shock response has been observed in *Listeria monocytogenes*, *Salmonella spp.*, and *Escherichia coli* (Novak and Juneja, 2003; Hansen and Knochel, 2001; Juneja et al., 1998; Murano and Pierson, 1992; Bunning et al., 1990; Farber and Brown, 1990; Mackey and Derrick, 1986).

Listeria monocytogenes

Listeria monocytogenes is a primary pathogen of concern as it is an anaerobic organism that is both resistant to high temperatures and is psychrotolerant in nature (Hansen and Knochel, 1996). Growth at refrigerated temperatures and survivability in adverse environments, including those intrinsic factors that occur in minimally processed foods have made *Listeria monocytogenes* a challenge to control (Novak and Juneja, 2003). The actual amount of time that cells are heat shocked influences the subsequent development of heat resistance in *Listeria monocytogenes* (Hassani et al., 2007). Work by Farber and Brown (1990) showed *Listeria monocytogenes* heat shocked for 120 minutes exhibited an average 2.4-fold increase in the decimal reduction time at 64 °C; 8.0 minutes respectively, when compared to 0.0, 30.0, and 60.0 minutes. Moreover, Farber and Brown (1990) revealed heat shocked cells at 4 °C maintained thermotolerance for at least 24 hours after heat shock. Work by Hansen and Knochel (2001) showed an increase in the log reduction times of *Listeria monocytogenes* in the late logarithmic phase when meat samples were subjected to a heat pretreatment of 46 °C for 30 minutes. Novak and Juneja (2003) indicated that heat-treated ground meat can activate adaptations in *Listeria monocytogenes,* enabling the foodborne pathogen to survive a second low temperature reheating following chilled storage and prior to ingestion by the consumer. Temperature abuse must be limited due to the ability of *Listeria monocytogenes* to recover from heat shock and subsequent lethality heat resistance.

Salmonella

Salmonella is a heat resistant, gram-negative, rod-shaped bacilli responsible for an estimated 1.2 million illnesses in the U.S., with roughly 23,000 hospitalizations and 450 deaths (CDC, 2014). Raw foods of animal origin can potentially carry *Salmonella.* As cited by Baldwin (2012) in reference to Snyder (1995); a 3 $\log_{10}$ unit reduction in *Salmonella* species should be sufficient for healthy individuals; whereas, a 6.5-7 $\log_{10}$ unit reduction should be sufficient for immunocompromised individuals. Work by Bunning et al. (1990) demonstrated an increase in *Salmonella spp.* thermotolerance after sub-lethal heat shock at 48 °C for 30.0 minutes. Likewise, research by Mackey and Derrick (1986) showed pre-incubation of *Salmonella* cells at 48 °C for 30 minutes increased their resistance to subsequent cooking at 50 °C, 52 °C, 55 °C, 57 °C, and 59 °C resulting in elevated heat resistance persisting for at least 10 hours.

Escherichia coli O157:H7

Escherichia coli O157:H7 is a deadly shiga-toxin producing, pathogenic strain of *Escherichia coli* bacteria with an extremely low infectious dose resulting in an estimated 2,138 hospitalizations annually. This pathogen is commonly associated with ground beef since the microorganism lives in the bovine rumen (CDC, 2013; 2012). Murano and Pierson (1992) subjected *Escherichia coli* O157:H7 to a heat stress at 42 °C for 5 minutes followed by a cooking treatment at 55 °C for up to 60 minutes. The number of injured cells was higher in heat-shocked cells when compared to controls, and the rate of release of cell components was higher in heat shocked cells as well. Most importantly, Murano and Pierson (1992) concluded, "Heat shock did not afford protection to the cells against injury, but rather enhanced their ability to recover during storage". Similar work by Juneja et al. (1998) found when ground beef containing *Escherichia coli* O157:H7 was heated at 46 °C for 15 or 30 minutes before exposure to re-heating to an internal temperature of 60 °C, the thermotolerance of the *Escherichia coli* cells were substantially increased and the organism survived longer than non-heat shocked cells.

Shelf-life

Shelf-life Overview

The shelf-life of a fresh meat product is defined as the length of time prior to becoming unpalatable or unsafe for human consumption or the loss of consumer appeal or color acceptance (Romans et al., 2001). The shelf-life of ground beef is an important consideration given the fresh beef product is so widely consumed and utilizes more retail space than any other single fresh beef product (Rogers et al., 2014; Mize and Kelly, 2004). Sixty percent of all in-home beef servings contain ground beef (Kerth et al., 2015; Cattlemen's Beef Board and National Cattlemen's Beef Association, 2009). Mechanical refrigeration is the most common means of extending shelf-life (Romans et al., 2001). Nonetheless, product shelf-life can be readily influenced by packaging materials, storage, and the display case characteristics (Steele et al., 2016; Rogers et al., 2014; Martin et al., 2013; Jeremiah and Gibson, 2001). The retail display case is the weakest link in the cold chain due to inconsistent storage conditions (Rogers et al., 2014; James and Bailey, 1990).

Storage Conditions

Retail-ready ground beef is primarily packaged in oxygen permeable films, chubs, or in modified atmospheric conditions comprised of oxygen, carbon dioxide, carbon monoxide, nitrogen dioxide, or nitrogen in mixtures. Research by Rogers et al. (2014) suggested a relationship between color, odor, biochemical, and microbiological factors during the course of refrigerated and abusive display environments on anaerobic and aerobic package types. Rogers et al. (2014) found anaerobic ground beef packaging samples, including vacuum-packaging and modified atmospheric packaging, exhibited pronounced color stability and ultimately presented minimal discoloration throughout the trial as well as reduced negative odor profiles throughout the course of temperature abuse and refrigerated display. Anaerobic packages revealed the least oxidative rancidity.

Storage temperature and display factors including lighting-type produce detrimental effects on color and retail appearance (Jeremiah and Gibson, 2001). Data from Jeremiah and Gibson (2001) demonstrated that storage of fresh beef at -1.5 °C provides the greatest color stability, the most desirable retail appearance, and the longest storage-life and retail case-life for fresh beef. Most notably, storage life was more than doubled for retail-ready beef steaks by storage at subzero temperatures, specifically at -1.5 °C. More recent literature by Martin et al. (2013) concluded that temperature directly influences the shelf-life properties of traditionally packaged ground beef through the enhancement of spoilage determinants, such as microorganism proliferation and lipid oxidation, at higher storage temperatures. Martin et al. (2013) reported storage of ground beef chubs at 2.3 °C for 28 days resulted in a more rapid appearance of spoilage indicators as well as increased bacterial proliferation and the ability of consumers to notice changes in lean color after only 1 day of retail display versus similar product stored at -1.7 °C. Retail meat appearance and shelf-life also depends on display lighting type and intensity. Fluorescent bulbs are most commonly utilized in the retail display case. Regardless, recent research by Steele et al. (2016) evaluated modern lighting technologies for increased ground beef shelf-life. This data demonstrated the use of light emitting diode (LED) lighting in fresh meat retail display cases offers benefits including the extension of the color life of ground beef by at least 12 to 24 hours longer versus florescent lighting due to the ability of LED lighting to produce light in a very specific band of wavelengths; ultimately eliminating color-damaging ultraviolet light. Moreover, LED lighting shows more efficient condenser cycling and energy usage, and importantly colder operational temperatures (Steele et al., 2016).

Palatability and Eating Quality Experience

Palatability and Eating Quality Experience Overview

Meat palatability is often defined as palate sensory experience resulting from perceived tenderness, juiciness, and flavor. Moreover, palatability can be presented as a simple, yet highly variable, equation that combines the three main associative traits. This results in a positive or negative eating quality experience. The equation is presented as follows:

EATING QUALITY EXPERIENCE = (TENDERNESS) + (JUICINESS) + (FLAVOR)

A consumer's overall eating quality experience is highly correlated to tenderness, juiciness, and flavor desirability and intensity; Neely et al. (1998) found simple correlations of 0.85, 0.77, 0.86, and 0.79 between overall eating quality experience and the respective quality characteristics.

Tenderness is the most important palatability trait to consumers (Huffman et al., 1996). Tenderness can be described as the "ease of mastication". Historical literature has shown tenderness is most commonly influenced by connective tissue content and muscle fiber contractile state along with intramuscular fat and moisture content in raw fresh red meat (Forrest et al., 1975). Juiciness is essential to conveying palatability as it is a carrier for flavor-based compounds as well as a buffer to tougher fresh red meat cuts (Aberle et al., 2012). Juiciness is function of both moisture content and intramuscular fat. Flavor contributes to both physiological and psychological responses upon consumption through both organoleptic and oral sensations.

Without a doubt, flavor is one of the most complex traits related to palatability since thousands of volatile compounds contribute to the associated sensory experience (Mottram, 1998).

Tenderness

The "ease of mastication" or perceived tenderness is important due to its overall effect on palatability and resulting effect on price (Boleman et al., 1997; Harris & Savell, 1993). The palate sensation of tenderness has several components of varying importance. Tenderness is influenced by specific anatomical factors and linked effects: connective tissue (background effect), contractile state (actomyosin effect), protein interactions (bulk density effect or lubrication effect or actomyosin effect), and fat and moisture content (bulk density effect or lubrication effect) (Aberle et al., 2012). Connective tissue surrounds muscle at every level of organization; around the entire muscle as epimysium, around the muscle bundle as perimysium, and around the muscle fiber as endomysium. The lower percentage of intramuscular adipose tissue directly influences the toughness of the bovine muscles of locomotion as intramuscular adipose tissue weakens the structure of perimysial connective tissue by breaking away the collagen bundles as well providing lubrication during mastication (Brooks and Savell, 2004; Nishimura et al., 1999).

Juiciness

Juiciness is defined as the expressible moisture prior-to and upon mastication. Functionally, juiciness is essential to conveying palatability as it is a carrier for flavor-based compounds as well as a buffer to tougher fresh red meat cuts (Aberle et al., 2012). Literature suggests juiciness can be influenced by multiple tissue and handling factors including pH, total fat content, and the degree of protein denaturation or 'degree of doneness' (Judge et al., 1989). Moreover, as cited by Pearce et al. (2011) in reference to Honikel (2004) and Honikel et al.

(1986), water location and mobility will change due to numerous mutual interacting factors of both ante-mortem (breed, muscle, stress level and type etc.) and post-mortem nature (slaughter procedure, cooling rate, ageing time and temperature). Above all, juiciness is an additive combination of moisture and lipid content (Romans et al., 2001).

The majority of water in muscle is held either intramuscularly within actin and myosin, between the myofibrils and between the myofibrils and the sarcolemma, or between muscle cells and muscle bundles (Huff-Lonergan and Lonergan, 2005). Since water molecules are polar, the molecules associate with the charged reactive groups of muscle proteins. Water in lean tissue can be classified as bound, immobilized, or free (Aberle et al., 2012). By definition, bound water has reduced mobility and exists in the vicinity of non-aqueous constituents such as proteins and lipids. Immobilized water molecules exhibit steric or hydrogen-based attraction to bound water molecules, but the attraction or bind becomes weaker as the distance from the reactive group decreases due to physical force exertion. Free water is held by weak surface forces. Importantly, the process of converting muscle to meat has a significant effect on the binding of water molecules due to the net charge of actin and myosin (Net Charge Effect), the structural components of the muscle cell and associated linkages and permeability (Exchange of Ions), and the amount of extracellular space within the muscle itself due to the completion rigor or lack there-of (Steric Effects) (Pearce et al., 2011; Judge et al., 1989). Myofibril structural changes have the greatest influence on juiciness due to immobilized and mobilized water fractions located within actin and myosin (Pearce et al., 2011).

Juiciness is both positively and negatively influenced the percentage of fat located within, between, and around outer surface of the muscle. Intramuscular fat can account for almost 50 % of the variability in perceived juiciness (Emerson et al., 2014). As intramuscular fat increases, the percentage of water decreases in muscle and ultimately, in fresh meat since lipid tissue contains little or no moisture (Romans et al., 2001).

Flavor

Brewer (2006) defines flavor as the combination of basic tastes and odor derived from water-soluble compounds and a myriad of substances present in the food product from the onset or derived via various reactions such as cooking. Species flavor and aroma arise from lipid constituents (diet), the subsequent heat treatment (maillard reaction) resulting in volatile formation, and lipid percentage (intramuscular fat) (Calkins and Hodgen, 2007; Judge et al., 1989). The major volatile compounds and resulting flavors and aromas associated with meat are shown in Appendix B.

Lipid constituents of lean muscle can be influenced by diet composition. Historical research by Westerling and Hedrick (1979) revealed both intramuscular and subcutaneous fat from fescue-based grass-fed animals contained more saturated fatty acids and less unsaturated fatty acids when compared to fat from animals that received a grain-based diet. Furthermore, dietary ingredients such as fish products, raw soybeans, canola oil and meal, and pasture grasses can cause undesirable flavors in red meat due to the increase in unsaturated fatty acids within the lean (Melton, 1990).

The heating of meat develops flavor via non-enzymatic or sugar-amine browning otherwise known as the Maillard reaction. Amine groups react with available reducing sugars in tissues to kindle the chemical reaction. The Maillard reaction occurs at high temperatures, 90 °C or higher, during direct, dry heat applications such as grilling, roasting, or broiling (Judge et al., 1989). Importantly, the sugar-amine browning reaction will not occur without direct heat; thus, the meat taste will be bland to the palate without the Maillard reaction.

Increased intramuscular fat directly influences flavor due to the amount of fat available for the formation of flavor compounds (Brewer, 2006). More specifically, the USDA Select quality grade corresponds to an intramuscular fat percentage of 2.3 to 3.9, whereas the USDA Prime designation will contain an intramuscular fat percentage of 9.9 to 12.3 (Wilson et al., 1998). Appendix C displays USDA quality grades (Overall A-maturity), and associated intramuscular fat percentages. Well-established research by Savell and Cross (1988) evidenced the minimally acceptable amount of intramuscular fat content needed for a positive eating quality experience is 3.0 %. Additionally, as intramuscular fat content increases, overall acceptability and positive eating quality also increases (Savell and Cross, 1988).

Consumer Appeal and Palatability Preference

Color Acceptability

A consumer's first perception of eating quality is with their eyes, followed by smell, and lastly by taste. Thus, color acceptability drives the initial perception of palatability and preference leading ultimately to the purchase of the fresh red meat product (Savell et al., 1989). In ranked order, purchase is typically driven by color, visible fat, price, and retail-cut type. For the consumer desiring a lean cut of fresh red meat, color, as opposed to marbling, is of greater importance to most consumers (Killinger et al., 2004). For fresh beef, consumers have shown willingness to accept a retail cut that is dark-red; nonetheless, at a ratio of 3:1, consumers prefer a bright, cherry red lean color (Killinger et al., 2004).

Tenderness

Arguably, tenderness is the most important palatability trait to consumers (Huffman et al., 1996). Tenderness is critical to beef palatability and has a major impact on a consumer's willingness to purchase, and the overall eating satisfaction experience (Fuez et al., 2004). Warner-Bratzler shear force is a common instrumental assessment of tenderness. A 0.5 kilogram difference in tenderness Warner-Bratzler shear force tenderness values can be detected by a consumer (Miller et al., 1995). Moreover, a 98 % customer satisfaction level can be achieved if Warner-Bratzler shear values are less than 4.1 kilograms (Huffman et al., 1996). Research by Boleman et al. (1997) found that overall consumer eating satisfaction decreased as tenderness decreased. Additionally, Boleman et al. (1997) showed that consumers can identify differences between tough and tender steaks and are subsequently much more likely to purchase steaks descriptively designated as 'tender' at a 94.6 percentage purchase rate over 'intermediate' or 'tough' designations. On average, a consumer is willing to pay more than a 1.84 premium per pound more for tender beef (Feuz et al., 2004; Lusk et al., 2001).

Juiciness

Juiciness is both a sensory and chemical meat component that is important to overall beef palatability (Emerson et al., 2014; Platter et al., 2003).The ability of fresh meat to retain moisture is one of the most important quality characteristics of raw products due to the positive effect of juiciness on the overall eating quality experience (Huff-Lonergan and Lonergan, 2005). Recently, Corbin et al. (2015) concluded an 8.4 % increase in the importance of juiciness as a consumer palatability preference when compared to similar survey work by Miller et al. (1995) and Platter et al. (2003). Moisture loss occurs due to evaporation and drip loss, and will increase with end-point cooking temperature (Forrest et al., 1975). As a result, the desire for a juicy meat product, regardless of detrimental cookery behaviors, has led to the use of brine injection to insure a juicy and palatable experience for the consumer.

Flavor

Meaty flavor and associated aromas stimulate numerous physiological and psychological responses including salivary release and hormone secretion. Flavor is one of the most complex traits related to palatability since thousands of volatile compounds contribute to the associated sensory experience (Mottram, 1998). Positive flavor characteristics are critical to the eating quality experience and sensory satisfaction. Taste has a positive impact on consumer attitudes towards fresh beef (Savell and Shackelford, 1992). Reicks et al. (2011) reported flavor as the greatest motivator for purchase of beef roasts and steaks, which is contrary to the majority of palatability preference and eating quality conclusions, which indicate tenderness is most important (Platter et al., 2003; Miller et al., 2001; Huffman et al., 1996). Once tenderness is within an acceptable range to a consumer, or when variation in tenderness has been reduced, then flavor becomes the most important determinant of beef consumers' assessments of overall satisfaction (Tatum, 2008; Behrends et al., 2005a, 2005b; Killinger et al., 2004; Goodson et al., 2002). Recently, Corbin et al. (2015) revealed that with a large percentage of the U.S. beef supply being classified as tender according to the National Beef Tenderness Survey (Guelker, 2013); the importance of flavor to overall beef eating satisfaction is magnified. In a 2015 survey, only 30.8 % of beef consumers believed tenderness was the most important palatability trait as opposed to a much larger 50.0 % of consumers in 1995; a 19.2 % decrease that has resulted in a preference shift towards flavor (Corbin et al., 2015; Miller et al., 1995). Appendix D depicts the changes in palatability preferences over time.

O'Quinn et al. (2016) found increases in consumer eating satisfaction and flavor perception were related to a buttery/beef fat flavor with higher marbled steaks indicating that degree of marbling is important for consumers' satisfaction. Intramuscular fat percentage has a positive effect on beef flavor perception regardless of its effect on tenderness, and that consumer overall liking and flavor scores are closely related to the fat-like flavor (Corbin et al., 2015). Furthermore, when asked to specifically describe beef flavor, consumers preferred descriptive terms such as beefy/brothy, brown/grilled, buttery/beef fat, nutty/roasted nut, and sweet as opposed to negative descriptors such as bloody/metallic, grassy, gamey, livery, sour, and bitter (O'Quinn et al., 2016).

Palatability Degradation

The gross components of lean tissue are as follows: water, protein, lipid, and ash. More specifically, fresh meat is comprised of approximately 72 % water, 20 % protein, 7 % fat, and 1 % ash (Romans et al., 2001). Water serves as a transport medium and is a major constituent in extracellular fluid and meat chemistry. Proteins constitute muscle mass and can be categorized as sarcoplasmic, myofribrillar, or stromal. Lipid content of muscle consists primarily of triglycerides and phospholipids found in both the intermuscular and intramuscular regions; and lastly, the inorganic constituents serve numerous physiological significance related to contraction (Judge et al., 1989). Given the primary constituents and ultimate chemical nature of lean muscle and fresh meat, meat is extremely volatile in regards to palatability due to reactions with the environment.

Lipid Oxidation

Oxidative rancidity negatively impacts beef flavor and overall palatability acceptance by the consumer (Campo et al., 2006). Lipid oxidation or auto-oxidation of unsaturated fatty acids can be described as degradation occurring from molecular oxygen at the membrane-level resulting in the production of free radicals that migrate to other double bonds and produce more free radicals causing rancidity in phospholipid fractions (Romans et al., 2001; Labuza, 1971). Thiobarbituric Acid Reactive Substances (TBARS) are indicative of the auto-oxidation of unsaturated fatty acids expressed in a sample. Ultimately, a ‘warmed-over’ flavor will be apparent and detectable by the consumer in the meat product due to the by-products of aldehydes, acids, and ketones and decomposition of fatty acid molecules (Gray et al., 1996; Judge et al., 1975). Established literature has indicated pro-oxidants such as calcium chloride, heat, ultraviolet light, low pH, and metal ions such as copper and iron can increase the rate of auto-oxidation (Judge et al., 1975). Additionally, freezing meat increases oxidative rancidity, due to damages in some cellular structures (Campo et al., 2006). Well-known auto-oxidation preventions include: the use of antioxidants, increase in fatty acid saturation, avoidance of oxygen exposure, decrease in storage time, storage as primals or subprimals due to decreased surface area exposure, and a decrease in pro-oxidant exposure. Research has shown Vitamin E supplementation in animal diets incorporates into phospholipid membranes and serves as a free radical scavenger; thus reducing lipid oxidation until the Vitamin E is consumed (Robbins et al., 2003). Furthermore, research has indicated plants and fruits such as crown daisy leaf, rosemary, and pomegranate extracts have high phenolic content and high antioxidant activity and thus the ability to inhibit lipid oxidation in ground beef (Turgut et al., 2016; Kim et al., 2013).

<u>Consumer Detectability</u>

Determination of malondialdehyde by the thiobarbituric acid reaction (TBARS) is a good predictor of the consumer perception of rancidity (Campo et al., 2006). Historical research by Greene and Cumuze (1981) revealed a large variation in the consumer detection threshold of oxidized flavor in beef, TBARS values ranging from 0.6 to 2.0. Campo et al. (2006) determined under experimental conditions, a TBARS value of 2.0 could be considered the limiting threshold for the acceptability of oxidized beef. Moreover, rancid off-flavor exceeds beef flavor in ground beef samples when a TBARS value exceeds 2.28 mg MDA/kg meat (Campo et al., 2006).

Spoilage Microorganisms

Spoilage is defined as an undesirable change in the flavor, odor, texture, and color of food caused by microbial proliferation and the associated enzymes ultimately leading to food unfit for human consumption due to putrification and deterioration (Davidson, 2003). As discussed by Marriott and Gravani (2006), physical changes caused by microorganisms are more obvious than the chemical changes, since microbial spoilage usually results in a more apparent change in physical characteristics such as color, body, thickening, and organoleptic properties. Other additional physical indicators include, but are not limited to, weight loss, dehydration, and drip loss. Spoilage conditions, aerobic versus anaerobic, determine the microorganism responsible for the spoilage of meat. Importantly, microbial spoilage not only challenges palatability at the consumer-level, but is a challenge to profitability at the retail and processing-level.

Pseudomonas spp.

Pseudomonas spp. is consistently associated with the low-temperature aerobic spoilage of fresh meats and is dominant in the spoilage of ground beef as the microorganism comprises nearly three-fourths of species and strains present at time of spoilage (Jay et al., 2003; Jay et al., 1967). Slime and sulfur off-odor characterize the physical changes in meat due to *Pseudomonas* spp (Nguyen-The and Prunier, 1989; Segal and Starkey, 1969). Research by Jay et al. (2003) confirmed that fresh beef that undergoes aerobic spoilage at refrigerator temperatures is spoiled by psychrotrophic bacteria, essentially all of which are gram-negative rods. Microbial dominance is due to the capacity of pseudomonads to grow faster than other competitive microorganisms at temperatures between 2 °C and 15 °C, and to utilize the simple constituents such as free amino acids, nucleotides, and carbohydrates (Jay et al., 2003; Gill and Newton, 1977). A study by Jay et al. (2003) proved the most rapid *Pseudomonas* spp. logarithmic growth occurs between days 5 and 9 in ground beef samples stored at temperatures of 5 °C to 7 °C. Data from Pennacchia et al. (2011) suggested the ability of *Pseudomonas* spp. to survive under vacuum during storage; nonetheless, detection occurred more frequently in meat stored in aerobic than anaerobic packaging conditions and environments. Additionally, Pennacchia et al. (2011) found *Pseudomonas* spp. to be the only spoilage organism in the aerobic environment to be present from day 0 to day 21 further displaying the dominance factor and ability to survive.

Lactic Acid Bacteria

Research by Dainty and Mackey (1992) showed a change in packaging atmosphere, e.g. anaerobic, will inhibit the respiratory pseudomonads and in meats cause a shift in the microflora to lactic acid bacteria. Lactic acid bacteria (LAB) are gram-positive. As described by Casaburi et al. (2015) and Pothakos et al. (2015), the processing environment can be an important source of LAB contamination for meat due to air and surface spreading and the introduction of indigenous microbiota, provided that suitable growth conditions at low temperatures and substrate availability, primarily glucose, are established in processing ‘microclimates’. Fermented and acidic odor and flavor characterizations are often attributed to lactic acid bacteria spoilage (Casaburi et al., 2015; Pothakos et al., 2015).

Palatability Assurance for the Consumer at the Industry Level

Palatability Assurance Overview

A single beef carcass affects over 500 eating experiences. Ante- and post-mortem palatability enhancement has primarily focused on tenderness due to the single trait's importance to the eating quality experience and overall consumer acceptance (Feuz et al., 2004, Platter et al., 2003; Huffman et al., 1996). Nonetheless, literature has suggested the importance of flavor and juiciness, which combined with tenderness, ultimately leads to taste satisfaction (O'Quinn et al., 2016; Corbin et al., 2015; Huff-Lonergan and Lonergan, 2005; Harris and Savell, 1993).

Feedlot

Pre-harvest management practices are an important set of topics and are critical to ensuring a palatable beef product. The understanding of consumer preferences and ability to adapt to quality and production goals is essential to the success of the 21st century producer. The evolution of beef system practices has led to the development of Total Quality Management systems which focus on defect prevention at the producer level rather than inspection and subsequent discounts at the packing house (Tatum, 2006). Key elements of effective pre-harvest tenderness management processes include, but are not limited to genetic inputs and growth/performance technology application as well as husbandry skills (Tatum, 2006).

Genetics

Modern meat production cattle in the United States can be classified into two major types: 1.) *Bos taurus* (British or Continental) or 2.) *Bos indicus* (Brahman). Furthermore, the most widely used breeds associated with each classification are as follows: British – Angus, Hereford, Red Angus; Continental – Charolais, Gelbvieh, Limousin, Simmental; Zebu – Brahman (Tatum, 2006). Producers often diversify the herds through heterosis, by utilizing and balancing the strengths of each breed to form a crossbred animal which has positive growth performance, high cutability, and increased intramuscular fat deposition as well as environmental tolerance. For example, Angus cattle exhibit higher marbling scores on average (SM^{88} - low choice), consistency in merchandizing (88 % USDA Choice or higher) and the lowest shear force values (4.0 kilograms) when compared to Brahman; SL^{73} - high select, 30 %, and 5.9 kilograms, respectively (Wheeler et al., 2005, 2001). Nonetheless, the Angus breed is not as environmentally sound in the southern climates when compared to the genetic adaptability and heat resistance exhibited by Brahman cattle. Thus, a superior animal (Brangus) can be seen when combining the traits of both Angus and Brahman cattle for production in warmer, humid, tropical climates. However, Johnson et al. (1990) revealed shear force increases as percentage of *Bos indicus* increases in the commercial animal ultimately leading to unacceptable palatability; a 75 % influence of Brahman equals a shear force value of 5.5 kilograms.

<u>Maturity</u>

A major component contributing to the toughness of meat is connective tissue as it influences the qualitative characteristics of meat; specifically related to background tenderness (Forrest et al., 1975). Connective tissue surrounds muscle at every level of organization: around the entire muscle as epimysium, around the muscle bundle as perimysium, and around the muscle fiber as endomysium. Perimysium connective tissue has the greatest effect on tenderness.

As the animal ages, the percentage of soluble collagen in bovine muscles of locomotion (round and chuck) as well as support (rib and loin) significantly decreases leading to a greater percentage of stronger, more stable crosslinks known as the insoluble collagen fraction (Nishimura et al., 1996). Increased collagen diameter and the development of mature crosslinks results in toughness and reduced eating quality satisfaction in muscles with previously high immature divalent connective tissue content (Purslow, 2004). As a result, the toughness of beef muscles increases linearly with age; doubling from 0 months to 32 months of age (Nishimura et al., 1996). Mature crosslinks cannot be solubilized during heat treatment. Given the phenomena, almost half of all mature beef products will result in an undesirable sensory and palate experience (Harris and Savell, 1993). Thus, slaughtering cattle below 30 months of age (A-maturity) can result in reduced tenderness variation due to insoluble collagen fraction increases.

As an animal matures, the fresh lean color becomes much darker in appearance. As previously noted, lean color is the customer's first perception of possible eating satisfaction and therefore drives purchase. Lean color changes, from a 'youthful, bright, cherry red' to 'purplish-maroon', can be observed from 9 to 30 months (A), 30 to 42 months (B), 42 to 72 months (C), 72 to 96 months (D), and 96 or more months (E). Ultimately, a consumer will not purchase a fresh beef product if the lean appeal is undesirable (Killinger et al., 2004).

Gender

Steers and heifers represent a significant portion of the slaughter cattle population in the United States. Typically, heifer's exhibit higher marbling scores due to increased fat deposition at lower finishing weights than steers; nonetheless, steers produce more tender steaks (Tatum et al., 2007; Choat et al., 2006). Warner-Bratzler shear force values can differ up to 1.0 kilograms between a steer and a heifer (Tatum et al., 2007). Additionally, 22.9 % of steaks from a heifer carcass will be tough when compared to only 8.6 % of steaks in steers; and 11.1 % of steaks will exhibit dark lean color, thus reducing color acceptability (Voisinet et al., 1997). Research has found steak toughness in heifers can be attributed to increased calpastatin which inhibits the calpain enzyme system from inducing tenderization through protein degradation at the Z-line (Wulf et al., 1996). Endogenous estrogen activity has also been observed to negatively affect tenderness (Choat et al., 2006).

Growth Enhancement Technology

The utilization of hormones as an implant is a safe and effective production tool employed by the beef industry to ensure efficiency and resource sustainability with the ultimate goal of using technology to develop the perfect feedlot animal. Research indicates implants improve growth rate, feed efficiency, and beef carcass leanness (Preston, 1999). Beef producers in the United States are able to select between five possible hormones for implants and associated regiments; three are considered natural and two are described as synthetic. Testosterone, estrogen, and progesterone comprise the natural hormone group; whereas, zeranol and trenbolone acetate are the two synthetic hormones available for beef production. Reports indicate in 2011, an estimated 90 % of cattle in feedlots were implanted at least once regardless of animal weight or feedlot head capacity (USDA-APHIS, 2013). The use of implant strategies in beef production results in carcasses with increased percentages of edible meat yield and decreased fat deposition ultimately leading to more pounds of lean beef which some consumers desire (Dikeman, 2007; Platter et al., 2003; Reiling and Johnson, 2003). Furthermore, implant regiments in beef production will not affect the beef flavor attributes and mouthfeel highly desired by consumers (Barham et al., 2003).

Pre-harvest Stress

Animal stress, both short-term and long-term, has negative effects on palatability-influencing meat quality attributes. Ultimately, stress has the greatest effect on post-mortem muscle pH due to the relationship between glycogen and lactic acid (Apple et al., 1995). Glycogen depletion prior to harvest is a direct result of physical exertion and psychological stress (Immonen and Puolanne, 2000; Nockels et al., 1996). Ante-mortem stress sources include both phenotypic and genotypic factors including human handling and genetic pre-disposition (Grandin, 1980). Direct responses to the stress factors include fear, dehydration, hunger, physical activity and associated fatigue, and self-injury. Pre-harvest stress can induce dark, firm, and dry (DFD) lean characteristics in beef cattle.

Dark, firm, and dry lean is characterized by a dark purplish-red lean color as a result of high pH (greater than 5.7), due to excess muscle glycogen and a reduction in lactic acid, has no acceptance among consumers as it relates to the purchase of a ribeye or striploin steak (Bass et al., 2008; Lawrie and Ledward, 2006). In the 2011 National Beef Quality Audit (NBQA), a comprehensive review and outlook of the current beef industry, 3.2 % of slaughter cattle exhibited dark, firm, and dry lean; a notable increase from both the 2000 and 2005 NBQA studies which indicated 2.3 % and 1.9 % of slaughter cattle displayed the characteristic, respectively (McKenna et al., 2002; Garcia et al., 2008; Moore et al., 2012). Carcasses designated as dark, firm, and dry can be subjected to a loss of 50 % or more in value given the lean will be used in ground beef production (Mach et al., 2008).

Packer

Post-mortem palatability enhancement is primarily directed to tenderness. Without question, post-mortem tenderization and palatability improvement is a complex process that is affected by numerous factors including rate of post-mortem pH decline, temperature, time, and uncontrollable genetic factors (Aberle et al., 2012). Additionally, research suggests post-mortem tenderization is the result of two different phenomena: 1) proteolytic degradation of cytoskeletal proteins i.e. 'sarcomere scaffolding'- nebulin and titan during post-mortem storage caused by the calpain system and 2) alterations in actin/myosin interaction and associated cross-bridges (Goll et al., 1975). Therefore, post-mortem tenderness improvement technologies are strategies to cause sarcomere lengthening and disruption of myofibrils and stromal proteins.

Electrical Stimulation

Electrically induced contraction and relaxation cycles during the beef harvest cycle will result in more tender beef (Smith et al., 2008; McKeith et al., 1981a, 1981b). Electrical stimulation in the beef industry occurs at either high or low voltage; 450 volts versus 60 volts. The advantages of using high voltage electrical stimulation include an altered rate of postmortem pH decline, creates tears in muscle fibers, expedites the proteolytic activities of both cathepsins and calpains, and expends energy, thereby lessening sarcomere shortening occasioned by development of rigor mortis (Smith et al., 2008). Therefore, electrical stimulation improves tenderness by preventing excess muscle shortening (Smith et al., 2008; Hwang et al., 2003)

Mechanical Tenderization

A major component contributing to the toughness and quality characteristics of bovine muscles of locomotion is connective tissue (Forrest et al., 1975). Mechanical tenderization is utilized extensively in the United States to improve the palatability of whole-muscle meat as the process disrupts the structural integrity of myofibrils, muscle fibers, and muscle bundles as well as severing collagen, elastin, and reticulin fibrils (Smith et al., 2008). An estimated 2.6 billion pounds of fresh beef sold in the United States is mechanically tenderized with 75.1 % destined for food service and 13.3 % for retail (Muth et al., 2012; George-Evins, 2000). Primal and sub-primal cuts from the round, sirloin, and chuck will receive a mechanical tenderization treatment due to the increased perimysial and endomysial connective tissue fraction within the lean. Moreover, quality grade and the specific muscle are used as determinants of passing rate and frequency; meaning, muscles with lower intramuscular fat content and high connective tissue fraction will receive a greater frequency of passes; up to 2:1 ratio (George-Evins et al., 2000). Specifically, 35 % of prime cuts were mechanically tenderized as compared to 86.8 % of both USDA Select and Standard; respectively (George-Evins et al., 2000).

Injection

The injection of chemical ingredients into meat serves to increase product juiciness and reduce lipid oxidation as well as rapidly, 7 days as opposed to 17 days, improve tenderness (McGee et al., 2003; Sheard et al., 1999; Kerth et al., 1995; Wheeler et al., 1993). Sodium chloride and phosphates are typically used in the brine to achieve the aforementioned palatability enhancements. As summarized by Smith et al. (2008), phosphates enhance the water-holding capacity of meat and the sodium chloride activates the calpain enzymes due to the calcium ions. Wheeler et al. (1993) established that sodium chloride can improve palatability traits without negatively impacting lean color. Moreover, data from Kerth et al. (1995) showed the injection of either 200 or 250 mM calcium chloride can improve tenderness by 18 %. Yield research by Sheard et al. (1999) demonstrated the inclusion of phosphate in loins reduced cook loss and subsequently increased juiciness values when compared to untreated loins. Furthermore, McGee et al. (2003) found the injection of sodium tripolyphosphate can serve as a flavor protectant due to the ingredient's antioxidant properties.

Aging

Postmortem aging or proteolytic degradation for an extended period of time can improve palatability and reduce tenderness variation in beef via loss of integrity of sarcomeres. Postmortem aging can be classified as either wet or dry. Wet aging involves the beef cut being held in sealed, oxygen impermeable, vacuum bags for an extended period of time; whereas, dry aging relies on the product being held in temperature and humidity controlled environment with zero packaging protection (Smith et al., 2008). Wet aging is most prevalent in the retail and food service industry due to convenience and since nearly all, 90 %, of beef sold in the United States has been marketed and distributed as vacuum packaged, boxed beef (Savell, 2008). Both of these methods improve tenderness and cause flavor specific flavor identity; however, dry aging results in lower yields and shrinkage due to moisture- and trim-loss, thus leads to higher prices for the customer (Savell, 2008; Smith et al., 2008)

Optimal aging times for tenderness depend on the specific muscle and associated quality grade (Gruber et al., 2006; Bratcher et al., 2005). The greatest extent of proteolysis occurs within the first 11 days (Bratcher et al., 2005). A-maturity beef exhibiting marbling scores greater than Modest^{00} – average choice do not need to be aged beyond 7 days; however, lean designated USDA Select should be aged a minimum of 14 days. However, muscle type (locomotion versus support) affects the rate of proteolysis, and therefore, aging time (Gruber et al., 2006). Research by Gruber et al. (2006) evidenced muscles of support, *Longissimus dorsi* and *Psoas major*, can achieve an optimal shear force values of 4.1 kilograms as described in 1996 by Huffman et al. in

7 days or less; whereas, muscles of locomotion such as the *Semimembranosus* and *Triceps brachii* can take 28 days or longer.

The primary purpose of the dry aging method is to impart and further enhance flavor (Savell, 2008). Dry aging imparts an intense and savory, full beef flavor in combination with nutty, roasted aromatics (Savell, 2008). The burnt and toasted aromatics are due to the high oxygen environment and derivatives of 2-methyl-3-furanthiol (Brewer, 2006; Rowe, 2002). Contrastingly, wet aging results in bloody and serum flavor notes due to the moist environment of the aging conditions within the package (Brewer et al., 2006).

Summary and Conclusions

Food waste is a costly epidemic in the United States to both the economy and environment. An estimated 31 % of food loss occurs at the retail and consumer levels which correspond to billions of dollars of economic loss and cost (USDA-OCE, 2016; USDA-ERS, 2013). Food is wasted due to misbranding, not meeting specifications, expired shelf-life, consumer confusion of packaging dates, lack of accountability or audits, too much emphasis placed on aesthetics, and most notably, improper consumer handling behavior (USDA-OCE, 2016; Gunders, 2012). Improper consumer handling behaviors ultimately lead to food waste and reduced sustainability both domestically and globally.

An enumerable amount of years and dollars by both industry and academia have been directed to assuring a wholesome and palatable fresh beef product on the plate. Nonetheless, consumers do not protect purchased fresh red meat products from temperature abuse nor are they concerned about the possible detrimental effect to palatability regardless of the demand for a tender, juicy, and flavorful fresh red meat product. Astoundingly, less than 10 % of consumers immediately return to residence with temperature dependent food items in the vehicle, and only 7 % use a cooler to protect cold food items during transport (Godwin and Coppings, 2005). Furthermore, consumers do not know the actual temperature of their refrigerator or freezer; and regardless of established and published minimum temperature thresholds for meat products, consumers are unable to accurately verify internal temperature, since only 31 % of consumers actually use a food thermometer (Cates, 2007). Research has revealed that at some point in time during the consumer cold chain, a meat product will be in an unacceptable temperature range for a given bacteria; therefore, inducing logarithmic growth and product degradation leading to food safety and palatability concerns (Cates, 2007; Godwin and Coppings, 2005). Temperature abuse can result in pathogen resistance to heat and the formation of negative organoleptic characteristics due to spoilage microorganisms (Weddle-Schott, 2007).

Without question, there is a continued need for consumer outreach and the research of handling behaviors for meat. To date, the majority of literature has emphasized proper in-home handling behaviors, and no literature has addressed the effect of temperature abuse on meat palatability during vehicular transport from grocer to residence. Moreover, only one consumer study has minimally identified how consumers handle groceries during transport from grocer to residence. Thus, direct consumer cold chain research will not only provide consumers with knowledge needed to improve handling behaviors, but give the meat industry a greater understanding of consumer behavior. The meat industry will be able to further focus and develop future technological improvements and marketing strategies for this specific consumer behavior.

Research Objectives

Unlike the controlled and highly regulated systematic steps in the production and handling of the fresh red meat product prior to purchase, a consumer's handling behavior cannot be regulated by an outside authority after the product has left the retail setting. Although the commercial cold chain and retail segment have been provided with scientifically sound technical guidance for time and temperature (i.e. Food Code provisions), information related to the consumer cold chain is limited. The study of handling behavior from grocer to residence is limited due to a combination of complexity and variability as well as the cost of research. No research has assessed improper consumer handling behaviors during transport from retail to residence. Thus, a critical problem in the field of meat science is the lack of understanding of consumer handling practices during transport from retail to residence, and the subsequent effect on desired palatability traits.

The objective of the first study was to investigate consumer behaviors regarding fresh beef product handling, specifically during the period of transport from retail to residence, utilizing an electronic questionnaire. Utilizing the Qualtrics platform and validity from subject field experts, the survey addressed specific consumer handling behaviors that occur during the transport of fresh beef products from retail to residence. Survey questions pertained to selection of fresh beef products, shopping time, product placement in vehicle, use of personal cooler, and time from retail to residence including stops prior to residence. Dissemination was a cooperative effort between Auburn University, state extension agents, and peer to peer given the use of social media as the distribution tool for convenient sampling of beef consumers who were 19 years of age or older. No reward of any kind was used for recruitment; thus, participation was intrinsically motivated. Upon completion, the survey was statistically analyzed in-order to create consumer-based parameters and treatments for the second study.

The objective of the second study was multifaceted. The first objective was to determine the rate at which fresh beef products increase in temperature upon placement in cart or basket at retail locations, and the subsequent effects on palatability and consumer appeal. Ground beef was chosen as the raw material source. The experimental parameters were determined by the findings observed in the first study. Designated ground beef samples were removed from the retail case and held at an environmental temperature of 21.2 °C for either 0 minutes, 10 minutes, 20 minutes, 30 minutes, minutes to greater than 4.4 °C internally, and 360 minutes, given the randomly assigned treatment designation. Meat color evaluations, purge percentage, and off-odor were assessed on each treatment sample. Individual treatment samples were then divided into three equal portions, and randomly assigned to three analyses (1. Thiobarbituric acid reactive substances; 2. Cook loss and Allo-Kramer shear force; 3. Sensory evaluation). Additionally, a 10 day comparative color acceptability study was performed on 0 minute (control) and 49 minute (TTF) treatment samples. Data was statistically analyzed.

The next objective was to understand the implications of improper consumer handling behaviors during transport from retail to residence on meat quality. Ground beef was chosen as the raw material source for experimentation. The experimental parameters were determined by the findings observed in the first objective. The principle design of the experiment was to place ground beef samples in the rear and trunk of a vehicle with air-conditioning on, air-conditioning off, and to run an errand; thus, turning the vehicle off for a period of time and then back on. Additionally, the impact of the aforementioned environmental factors was evaluated on the internal temperatures of insulated cooler bags with or without ice. Subjective and objective evaluations were performed as described in the first objective of this study.

Ultimately, this research was designed with the consumer in mind and the goal was to mimic the way a consumer would handle fresh beef products during vehicular transport from retail to residence

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Chapter II: Preliminary Research

Preliminary Study I: Consumer Survey

Materials and Methods

The target population(s) for this study were individuals 19 years of age or older enrolled at Auburn University (Auburn, AL) who actively participated as a student in the course titled: Survey Research Methods (Course Number: ERMA 8200/8206) who consume fresh beef products. Convenient sampling occurred through the creation of a "Discussion" on the ERMA 8200/8206 course Canvas link that allowed for instrument distribution (Canvas Network, 2016). An appropriately designed, two-minute survey questionnaire (constructs: time, placement, insulated storage) was developed over a three-month period (January 2016 to March 2016) and implemented (March 2016 to April 2016) using Qualtrics survey software (Qualtrics LLC, 2016). A selection item scale was used for nominal measurement. Participants were asked to answer nine survey items related to fresh beef handling practices at the grocer and during transport along with four demographic-based survey items. Participants were given an informed consent form. All data analysis was performed using SPSS (Version 22). Responses were excluded if 80% of the survey was not complete. Descriptive analysis was used to generate frequency distributions. A Chi-square test was used to test significance ($P < 0.05$). A reliability statistical analysis was not performed since all questions were factual. Survey content and face validity was established by members in the subject field.

Results

A total of 15 responses (26 responses with a 23 % drop-out rate) were analyzed. Approximately 80 % of respondents shop for groceries between the hours of 12:00 P.M. and

8:59 P.M. with the majority (46.7 %) of respondents shopping between the hours of 5:00 P.M. and 8:59 P.M. Upon fresh red meat selection and placement in the grocery cart or basket, 100 % of respondents check-out in less than 30 minutes with 80 % of participants heading to checkout between 6 and 20 minutes after selection and placement. Upon check-out, 93.3 % of respondents return home from the grocery store in 20 minutes or less with the majority of individuals returning home in 10 minutes or less. When asked about the placement of fresh beef products in vehicle, respondents claimed to place the products in the front (20 %), rear (33.3 %), and trunk or cargo space (46.7 %), respectively. Approximately 60 % of respondents ran errands after purchase and placement of the fresh beef product in the vehicle. The majority of respondents (44.4 %) indicated the fresh beef product was left in the vehicle for 31 to 60 minutes while running errands. Of the 15 total responses, zero respondents "always" used an insulated product during transport with "frequently" and "occasionally" only totaling 26.7 %. Notably, 73.3 % of individuals admitted to "never" using an insulated product during the transport of fresh beef in a vehicle. For the respondents who claimed to use an insulated product for fresh beef transport, an insulated bag or personal size (14.8 quart) cooler is used for temperature abuse protection. Gender had no influence on fresh beef product handling during vehicular transport from grocer to residence. Age significantly influenced the period of time a fresh beef product was left sitting in a vehicle while running other errands ($P < 0.05$).

Discussion

After the completion of the pilot study, an assessment was performed to evaluate any needed changes related to the survey instrument. Given the emphasis on food safety and consumer education, the fact that consumers do not readily use insulated products to avoid temperature abuse was of great concern. However, when compared to previous research by

Godwin and Coppings (2008), this study showed a 19.7 % increase in the use of insulated products (26.7 % vs. 7.0 %, respectively). Demographically, the study was not an accurate representation of the target population since all individuals had attained, at minimum, a bachelor's degree. Furthermore, the sample size (n = 15) is too small. It was determined that an increase in sample size (n = 385) would result in statistical significance.

Conclusions and Future Research

The preliminary study provided previously limited or missing information related to consumer handling and fresh beef products. Consumers tend to grocery shop in the afternoon or evening and upon purchase will typically place fresh red beef products in the trunk or cargo space for transport. Consumers are able to return to where they live in 20 minutes or less. Furthermore, during transport, the majority of consumers do not use an insulated product to prevent temperature abuse. Future research was needed to understand the subsequent effect of consumer handling behaviors during transport on fresh red meat palatability.

Preliminary Study II: Vehicular Temperature Monitoring in Front and Rear

Materials and Methods

Temperature loggers (n = 2) were used to record internal vehicle temperature and humidity at the front and rear of the vehicle. Two different vehicles (1. Truck; 2. Sport Utility Vehicle) were used at two independent starting dates representing independent trials (September 2-8 and 18-21, 2015). External environmental temperatures during the trial dates exceeded 32.2 °C. Data was analyzed utilizing Microsoft Excel to determine the highest observed temperature per location.

Results

The highest observed temperature for Vehicle 1 in the front location was 71.1 °C; whereas, Vehicle 2 produced a temperature of 62.2 °C in the respective location. Furthermore, in the designated rear location, temperatures of 50 °C and 43.8 °C were observed for Vehicle 1 and Vehicle 2, respectively.

Discussion

Observations indicated that internal vehicle temperatures were much higher than the environmental ambient temperatures during this period of time. Furthermore, it appeared that the front of the vehicle was a greater attractant to heat when compared to the rear of the vehicle. Moreover, based on time, protein denaturation and lipid oxidation could occur at the highest logged temperatures. Thus, palatability could be affected upon consumption due to the influx of temperature changes involved in the initial transport, refrigeration, and final cooking of the product prior to consumption.

Conclusions and Future Research

Regardless of vehicle type, results showed the front location of the vehicle produced higher temperatures when compared to the rear location. The temperatures observed were often associated with degrees of doneness, and more importantly are thermal processing temperatures utilized in a variety of cooking methods such as sous vide. Therefore, future research was needed to evaluate the impact of the aforementioned conditions on fresh meat palatability. Additionally, subsequent studies should evaluate the temperature of a trunk as well as the direct impact of vehicular temperature on internal fresh meat temperature.

Preliminary Study III: Vehicular Temperature Monitoring in Trunk

Materials and Methods

Temperature loggers (n = 3) were used to assess internal vehicular temperatures in the front, rear, and trunk of a four-door car on June 27, 2016 over a 30 minute period beginning at 11:00 A.M. The vehicle was not running and no air conditioning was used during the trial. Descriptively, the four-door car exhibited a white exterior color with a tan, cloth-based interior. Environmental temperatures during the trial dates exceeded 29.4 °C. Data was analyzed utilizing Microsoft Excel to determine the highest observed temperature per location.

Results

During the 30 minute trial, the highest observed temperature was seen in the front of the vehicle, 30 °C respectively. Moreover, the rear of the vehicle reached a temperature of 23 °C. Lastly, an observed temperature of 21 °C was produced in the trunk location.

Discussion

Although the observed temperatures were lower than the previous experiment, vehicular temperatures exceeded environmental temperatures. Thus, a vehicle conducts heat and can be internally higher in temperature than the environment. Furthermore, exposure to direct sunlight may explain the temperature differences per location.

Conclusions and Future Research

Results showed the trunk location of the vehicle produced lower temperatures when compared to the front or rear locations. The front location produced the highest observed temperature. Future research is needed to evaluate the impact of vehicular conditions resulting in an internal fresh meat temperature above 4.4 °C.

Preliminary Study IV: Fresh Meat Temperature without Air Conditioning in Vehicle

Materials and Methods

On July 14, 2016, ground beef samples (n = 5) were allotted to a total of three location treatments (n = 1 front; n = 2 rear; n = 2 rear in a hard-cooler with a single ice pack) and evaluated over a 35 minute period which included an errand stop to represent travel from grocer to residence (1.20 min; 2. 10 min with vehicle off to simulate errand; 3. 5 min). Temperature loggers where placed in each ground beef sample (n = 5) as well as the front (n = 1) and rear (n = 1) locations in the truck. Also, surface temperature was measured utilizing an infrared thermometer at minute 35. Data was analyzed utilizing Microsoft Excel.

Results

At the beginning of the trial, the front of the vehicle exhibited an average temperature of 36.5 °C and the rear displayed an observed temperature of 35.5 °C. At 20 minutes, average temperatures of 43.3 °C and 45.3 °C were recorded for the respective front and rear locations. During the ten minute errand simulation, average vehicle internal temperature in the front location increased to 46.3 °C and the rear location to 47.8 °C.

Initially, average internal meat temperatures of - 1.0 °C, 0.9 °C , and 3.7 °C were recorded for the front, rear, and cooler locations. At 20 minutes, temperatures of 6.5 °C, 6.8 °C, and 7.6 °C were observed for the respective front, rear, and cooler locations. During the ten minute errand simulation, average internal meat temperature in the front location increased to

11.0 °C, the rear location to 10.8 °C, and the cooler to 9.6 °C. During the final five minutes, average internal meat temperatures of 12.9 °C, 12.75 °C, and 10.7 °C were recorded for the front, rear, and cooler locations. Subsequent average surface temperatures recordings were as follows: 20.8 °C, 21.8 °C, and 17.1 °C for the respective front, rear, and cooler locations. Lastly, the internal temperature exceeded 4.4 °C in the front location at 16 minutes, 13.5 minutes in the rear location, and within 5.5 minutes in the cooler.

Discussion

In review, vehicular temperature results during the last five minutes of the trial were not presented due to environmental rain and the subsequent temperature decrease (~20 degrees) within the vehicle. Regardless, internal meat temperature continued to increase in the front and rear locations. Although, the cooler location showed the highest internal temperature after 20 minutes, the location exhibited the lowest increase in temperature during that same time period. Therefore, initial temperature must be taken into account; and should be controlled in future trials in order to reduce variance.

Conclusions and Future Research

Internal meat temperature increased over time regardless of location. Surface temperature was higher in the front and rear locations when compared to the cooler location. Also, surface temperature was considerably higher at minute 35 when compared to internal temperature across all respective locations. Importantly, the use of a cooler with an ice pack resulted in the lowest temperature increases. Nonetheless, during the 35 minute trial, all samples reached an internal temperature above 4.4 °C. Future research, should evaluate the effect of air conditioning on meat internal temperature during vehicular transport as well of the use of ice in a cooler.

Preliminary Study V: Fresh Meat Temperature with Air Conditioning in Vehicle

Materials and Methods

On August 2, 2016 at 3:25 P.M., ground beef samples (n = 6) were allotted to a total of three location treatments (n = 2 front; n = 2 rear; n = 2 rear in a hard-cooler containing ice) and observed over a 35 minute period which included an errand stop to represent travel from grocer to residence (1.20 min; 2. 10 min with vehicle off to simulate errand; 3. 5 min). Temperature loggers where placed in each ground beef sample (n = 6) as well as the front (n = 1) and rear (n = 1) locations in the truck in addition to the dash air vent (n = 1) and cooler (n = 1). Also, surface temperature was measured utilizing an infrared thermometer at minute 35. Upon sample placement in the vehicle, the air conditioning unit was turned on; a cool setting was selected to run at a medium fan speed with air blowing through both the floor and panel vents. Furthermore, the air recirculation feature was selected. Lastly, initial and post-treatment subjective color scores were assigned to treatment samples. Data was analyzed utilizing Microsoft Excel.

Results

At the beginning of the trial, the front of the vehicle exhibited an average temperature of 23.9 °C and the rear displayed an observed temperature of 25.3 °C. Initially, the cooler containing ice had a temperature of 2.0 °C. At 20 minutes, average temperatures of 25.1 °C and 25.6 °C were recorded for the respective front and rear locations. During the ten minute errand simulation, average vehicle internal temperature in the front location increased to 31.8 °C and the rear location to 28.8 °C. After the final 5 minutes, average temperatures of 25.9 °C and 26.0 °C were observed for the respective front and rear locations. After 35 minutes, the cooler registered an internal temperature of 3.6 °C. The air supply probe registered the following temperatures: 35.6 °C, 13.1 °C, 33.6 °C, 12.1 °C; respectively, for minute 0, 20, 30, and 35.

Initially, average internal meat temperatures of 1.9 °C, 1.95 °C, and 2.0 °C were recorded for the front, rear, and cooler locations. At 20 minutes, temperatures of 4.35 °C, 4.1 °C, and 2.8 °C were observed for the respective front, rear, and cooler locations. During the ten minute errand simulation, average internal meat temperature in the front location increased to 5.6 °C, the rear location to 5.3 °C, and the cooler to 3.35 °C. During the final five minutes, average internal meat temperatures of 6.25 °C, 5.9 °C, and 3.6 °C were recorded for the front, rear, and cooler locations. Subsequent average surface temperatures recordings were as follows: 11.1 °C, 11.1 °C, and 5.3 °C for the respective front, rear, and cooler locations. The internal temperature exceeded 4.4 °C in the front location at 20 minutes and at 21.5 minutes in the rear location. The internal temperature of the sample never exceeded 4.4 °C in the cooler with ice.

Finally, all samples received initial and post-treatment discoloration color scores of 2.

Discussion

The use of air conditioning in a vehicle during transport results in a cooler environment and reduced internal meat temperatures; nonetheless, samples in the front and rear exceeded an internal temperature of 4.4 °C. Additionally, it appears ice as opposed to an ice pack results in colder environment inside a cooler.

Conclusions and Future Research

The use of air conditioning during vehicular transport slows the internal temperature increase of meat. Regardless, a meat sample can exceed an internal temperature of 4.4 °C after

20 minutes. Using a cooler, with ice specifically, keeps meat out of the danger zone. Notably, future research will be based on consumer survey results.

Chapter III: Investigation of Consumer Behaviors Utilizing an Electronic Questionnaire on Fresh Beef Product Handling during Transport From Retail to Residence

Abstract

A critical problem in the field of meat science is the lack of understanding of consumer handling practices during transport from retail to residence. The objective was to investigate consumer behaviors regarding fresh beef product handling, specifically during the period of transport from retail to residence, utilizing an electronic questionnaire. A 13 item questionnaire utilizing the Qualtrics survey platform was randomly distributed across the United States through web-based platforms. A 43-day response period generated 1,554 responses with 1,484 completed questionnaires yielding a 95.5 % completion rate. All data was analyzed using IBM SPSS Statistics 22. The survey revealed 46.9 % of respondents shop between 5:00 P.M. and 8:59 P.M. Exactly 42.5 % of respondents' checkout between 11 and 20 minutes after fresh beef product selection and placement in cart. Upon check-out, 79.6 % of respondents return home from the grocery store in 20 minutes or less. Fresh beef products are most commonly placed in either the rear seat/floor of the vehicle or the trunk/cargo space for transport. Of the 25.8 % of respondents who ran errands with a fresh beef product left in the vehicle, 60.6 % admitted to leaving the fresh beef product in the vehicle between 6 and 20 minutes. Approximately, 55.7 % do not use an insulted-product to transport fresh beef products. An insulated bag is most commonly used for temperature abuse protection during vehicular transport. The questionnaire revealed age, sex type, ethnicity, and level of attained education influenced handling behavior in retail and during transport to residence ($P < 0.05$). Results indicate the need for continued dissemination of proper handling behaviors as well as scientific data to support the suggestions.

Introduction

Consumer questionnaire studies related to consumer product handling behaviors are scarce since only one consumer study by Godwin and Coppings (2005) has identified how consumers handle groceries during transport from grocer to residence. The face-to-face questionnaire covered constructs related to grocery product purchase, transport, and in-home handling behaviors.

The study by Godwin and Coppings (2005) revealed the majority of respondents, 44 %, go grocery shopping at least once a week. Furthermore, 82 % of respondents return-home in 20 minutes or less with 51 % returning-home in 10 minutes or less; importantly, 9 % of individuals took from 30 minutes to over an hour to return-home. Only 8 % of respondents immediately return to residence with temperature dependent food items in the vehicle, and 63 % of respondents admitted to going to more than one store while running additional errands. In the face-to-face survey respondents did not evidence concern of when or where the cold reliant food items were placed in the designated shopping cart; much less how the product was bagged for transport or when the product would be placed in the refrigerator. During transport, 52 % of food products are placed in the trunk of the vehicle, followed by the seat, and “in any/all depending on the amount”; 28 % and 25 %, respectively. Only 7 % of respondents admitted to using a cooler to protect cold food items. Consumers do not know the actual temperature of their refrigerator or freezer, and the majority of the respondents admitted to only adjusting the ‘temperature dial’ in the refrigerator once a year. Regarding food- storage, 94 % of respondents keep fresh meat products, both whole-muscle and non-intact products frozen. Furthermore, delicatessen and ready-to-eat meat products were typically stored in the refrigerator. Lastly, the study found consumers place meat products on the top-shelf of the refrigerator, and often-times have open containers or ready-to-eat products stored directly next-to raw meat products.

University extension programs have narrowly focused on in-home handling behaviors due to the lack of consumer-based research on actual handling behaviors. General suggestions found in literature include: purchase meat products before the sell by date in order to provide safe and nutritious food for consumers; select and pick-up refrigerated and frozen foods immediately prior to checkout since refrigerated foods should be cold, and frozen foods should be solid with no evidence of thawing; drive straight home with perishables placed inside the vehicle and kept on ice; and keep meat out of the danger zone; specifically between the temperatures of 4.4 ℃ and 60 ℃ (Boyer and McKinney, 2013; Weddle-Schott, 2007; Kilonzo-Nthenge et al., 2006; Burney, n.d.).

Given the volatility of meat quality stability due to reactions with the extrinsic environment, a greater understanding of consumer handling behavior in retail locations and during transport to residence is needed to provide educators, industry, and ultimately consumers with greater knowledge of proper handling behaviors and consequent accountability. Thus, the current study sought to investigate consumer behaviors regarding fresh beef product handling, specifically during the period of transport from retail to residence, utilizing an electronic questionnaire. Importantly, the results of this study formed actual consumer-based research parameters utilized in proceeding experimental designs.

Materials and Methods

Institutional Research Board Approval

The protocol entitled "The Consumer Cold Chain: Evaluation of Consumer Handling Behaviors on Fresh Red meat Products During Vehicular Transport from Retail to Residence and the Implications on Palatability and Food Safety" (Protocol # 16-245 EX 1607) was approved by the Institutional Research Board as "Exempt" under federal regulation 45 CFR 46.101(b)(2) on July 20, 2016. Protocol # 16-245 EX 1607 was approved for use from July 19, 2016 to July 18, 2019. All participants received an information letter prior to response.

Target Population

The target population of the study was fresh beef consumers 19 years of age or older since the project research objective was to evaluate the transport of fresh beef products and the subsequent impact on palatability.

Instrument

An electronic questionnaire was prepared at Auburn University over a five month period from January to May, 2016, prior to distribution on August 3, 2016, utilizing the Qualtrics electronic survey platform (Qualtrics Experience Management Platform, Qualtrics, North America). The preliminary questionnaire development began with item creation (n = 20) and construct determination (n = 3). The final electronic questionnaire produced items (n = 9) utilizing a selection item scale for nominal measurement with the constructs of time, product placement, and temperature protection. Respondent demographic questions (n = 4) addressed age, sex, ethnicity, and education. The final electronic questionnaire (including information letter, items, and demographic questions) is located in Appendix E.

Validity

Instrument validity was determined by trained personnel in the Department of Animal Sciences at Auburn University.

Sampling

Convenient sampling of survey participants was accomplished utilizing a social media platform (Facebook, Menlo Park, CA). An electronic link directed participants to the Qualitrics electronic questionnaire. No incentives were provided to participants for survey recruitment or completion.

Response

A 43 day response period (August 3, 2016 to September 15, 2016) was used for the study. A total of 1,554 responses were generated.

Statistical Analysis

Prior to analysis, the data was transposed to a spreadsheet file (Model Microsoft Excel; Microsoft, Redmond, WA, USA), and evaluated for respondent error and incompletion. A completion rate of 100 % was required for responses to be included in the study and subject to data assessment. Responses (n = 1,484; given a completion rate of 100 %) were analyzed using IBM SPSS Software v. 22 (International Business Machines Corp., Armonk, NY, USA). Frequency and chi-square analyses were performed on the respondent data.

Results and Discussion

Demographics

The total number of consumer responses for handling behaviors on fresh beef products during transport from retail to residence was 1,484. Tables 1, 2, 3, and 4 reveal the demographic profile of consumers that responded to the questions regarding handling behaviors. Age levels ranged from 19 – 24 years of age to 64 years of age or older. In this study, 66.2 % of consumer respondents were between 25 and 54 years of age (Table 1). Furthermore, 76.7 % of consumer respondents were female; and 23.3 % of consumer respondents were male, respectively (Table 2). In this study, 95.5 % of consumer respondents identified as Caucasian. Nonetheless, respondents identifying with Hispanic or Latino (1.8 %), African American (0.3 %), Native American or American Indian (0.9 %), and Asian or Pacific Islander (0.5 %) were included in the consumer study (Table 3). Education levels varied from non-high school graduate to attained college graduate degree. In this study, 75.9 % of all consumer respondents had at least an associate's degree from a higher education establishment (Table 4).

Comparisons of demographic information were made to data collected by the United States Census Bureau. Demographic information gathered in the current study was comparable to demographics of age. Moreover, roughly three-fourths of United States' citizens identify as Caucasian and recent consumer-based literature by Corbin et al. (2015) showed similar ethnic demographics. The average level of education for consumers in the current study was higher than the average for consumers in the United States. Furthermore, this study had a higher percentage of female respondents when compared to the sex type population of the United States.

Time in Retail and Return to Residence

In this study, 78.0 % of consumers went grocery shopping between the hours of 12:00 p.m. and 8:59 p.m. with the largest percentage of consumers (46.9 %) shopping in the evening between the hours of 5:00 p.m. and 8:59 p.m. (Table 5). Exactly 83.2 % of respondents admitted to checking out in 20 minutes or less after fresh beef product selection and placement in cart with the highest percentage of consumers (42.5 %) checking out between 11 and 20 minutes, respectively (Table 6). Moreover, 2.3 % of consumers admitted taking up to 60 minutes to check out after fresh beef product placement in cart (Table 6). Greater than three-fourths of consumer respondents returned to residence in 20 minutes or less upon leaving the grocery store (Table 7). This finding is in agreement with work by Godwin and Coppings (2005) that revealed 82.0 % of food shoppers return home in 20 minutes or less. This could be due to the relative abundance of retail food locations found in municipal environments across the United States. Importantly, the current study found it can take up to 120 minutes for consumers to return to residence. Approximately 74.2 % of consumer respondents claimed to 'never' run an errand with a fresh beef product left sitting in the vehicle (Table 8). Regardless, one-fourth of consumers indicate they will run an errand with a fresh beef product left sitting in the vehicle. Results from the present study disagree with a study conducted by Godwin and Coppings (2005) which concluded that 92.0 % of consumers will go run other errands with food products left in the vehicle. Moreover, the current study found that while completing an errand, fresh beef products will most often be left in the unoccupied vehicle for a time range between 6 and 10 minutes (Table 9). Exactly 27.7 % of consumer respondents admitted to leaving fresh beef products in an unoccupied vehicle for up to 20 minutes; whereas, 20.1 % of respondents claimed to return to the vehicle in 5 minutes or less (Table 9). Godwin and Coppings (2005) reasoned that persons living farther from available retail food locations would consolidate their travel and visit more than one store even though this further increases the time during which the temperature of cold foods could increase.

Placement in Vehicle

Approximately 87.7 % of consumer respondents indicated fresh beef products are most habitually placed in either the trunk or cargo space of the vehicle or the rear seat or floor, 45.4 % versus 42.3 %, respectively (Table 10). Furthermore, 11.5 % of consumer respondents routinely placed fresh beef products in the front seat or floor of the vehicle (Table 10). Lastly, nearly 1 % of consumer respondents admitted to placing fresh beef products in the bed of the pickup truck (Table 10). These results are in agreement with work by Godwin and Coppings (2005), which stated 52 % of consumers place purchased foods in the trunk or back of pickup.

Temperature Protection

Approximately, 55.7 % of consumer respondents indicated they never used an insulted-product to transport fresh beef products for temperature protection (Table 11). Scarcely, only 8.2 % of respondents always use an insulated product for temperature protection during transport (Table 11). In 2005, Godwin and Copings found 7 % of consumers whom grocery shop routinely use a cooler for all temperature dependent foods; a mere 1.2 % respective increase in 12 years. In this study, 36.2 % of respondents either frequently or occasionally used an insulated product during the vehicular transport of fresh beef products (Table 11). Exactly 44.3 % of respondents, who practice temperature protection at least occasionally, revealed a cooler bag is most commonly used as the designated insulated product type (Table 12). Moreover, for consumers who use a cooler, the respective sizes of 14.8 quarts to 40.0 quarts were most readily used for temperature dependent fresh beef product protection, 22.4 % accordingly. Table 13 reveals respondent brand preference for insulated product use.

Demographic Influence on Handling Behaviors

Table 14 depicts the effects of demographic influence on fresh red meat handling behaviors during vehicular transport from retail to residence. The questionnaire revealed age influenced the time of day grocery shopping occurred, time between fresh beef product selection and checkout, transport time from grocer to residence, fresh beef product placement in vehicle during transport, occurrence of running errands with a fresh beef products left sitting in vehicle, and the use and type of an insulted product to prevent temperature abuse ($P < 0.05$). A greater percentage of consumer respondents between 19 years of age and 54 years of age shop in the evening when compared to respondents 55 years of age or older. Additionally, after fresh beef product selection and placement in cart or basket, respondents 65 years of age or older check-out more rapidly when compared to all other age ranges present in this study. The largest percentage of respondents returning to residence in the least amount of time, 5 minutes or less, was those between 19 years of age and 24 years of age at 56.1 %. Alternatively, a greater percentage of individuals between 25 and 44 years of age took up to 30 minutes to return to residence. Next, a greater percentage of consumer respondents between 19 years of age and 24 years of age place fresh beef products in the front or back seat and floor locations; whereas a greater percentage of respondents 25 years of age or older place fresh beef products in the trunk or cargo space of the vehicle. Although the majority of all respondents, regardless of years of age, do not run other errands with fresh beef products in the vehicle; the greatest percentage consumers that do are between 25 years of age and 44 years of age. This could be due to time availability and household dynamics including careers and dependents. Lastly, the greatest percentage of respondents to use an insulated product for temperature abuse protection were 55 years of age or older. Notably, nearly three quarters of respondents between 19 years of age and 24 years of age never use an insulated product to protect fresh beef products from temperature abuse which is nearly 20 % greater than any other age group. The greatest percentage of all age groups used an insulated bag; however, if a cooler was used, consumer respondents between 25 years of age and 64 years of age used higher capacity sized cooler and when compared to those between 19 years of age to 24 years of age. This could be due to the volume of purchased food product as whole due to household dynamics.

Sex influenced the time of day grocery shopping occurred, time between fresh product selection and checkout, fresh beef product placement in vehicle during transport, and the use and type of an insulted product to prevent temperature abuse ($P < 0.05$). This study revealed female consumers shop at all times of the day, take longer to check out given the fresh beef product has been placed in the cart or basket, are more likely to place the fresh beef product in the trunk or cargo space of the vehicle during transport, and are more likely to use an insulated product for temperature protection with that product being an insulated bag than males. In contrast, male consumers favor shopping in the evening, check-out more rapidly, place the fresh beef product in the back floor or seat of the vehicle during transport, and are less like to use an insulated product to prevent temperature abuse.

Ethnicity influenced the time between fresh beef product selection and checkout out in addition to the occurrence and period of time running errands with a fresh beef product left sitting in the vehicle ($P < 0.05$). The study found consumer respondents identifying with Native American or American Indian ethnicity had the lowest duration of time between selection and checkout followed by both Caucasian or Hispanic or Latino ethnicities which averaged 6 to 10 minutes versus 11 to 20 minutes respectively. Furthermore, the greatest percentage of consumer respondents identifying with African American or Asian or Pacific Islander ethnicities indicated a 21 to 30 minute time period from selection to checkout. Compared to all other ethnicities in this study, exactly 75 % of Caucasian consumer respondents immediately return to residence immediately after food shopping. Whereas, approximately 60 % of African American respondents and 57.1 % of Asian or Pacific Islander respondents would at least occasionally run other errands with fresh red meat products left sitting in the vehicle. Additionally, in this study, the highest percentage of Caucasian or African American consumer respondents took between 6 minutes and 10 minutes to complete the errand; while Asian or Pacific Islander consumer respondents took between 11 and 20 minutes.

Level of attained education influenced transport time from grocer to residence ($P < 0.05$). The greatest percentage of respondents with attained higher education degrees reported less time required from a retail food location to residence when compared to respondents with an attained high school degree or equivalent or less than a high school degree, 20 minutes versus up to 60 minutes, respectively. Retail food centers can be devoid in non-metropolitan areas leading to increased transport times for these consumers due to economic reasons since metropolitan areas produce a higher median household income and have substantially lower poverty rates (58,260 vs. 44,212 dollars and a 14.3 vs. a 17.2 % poverty rate, respectively) (USDA-ERS, 2017). Research by Clark et al. (2008) found non-metropolitan retail food locations often close and never re-open because of lack of community support leading ultimately to low sales volume due to operating costs, labor availability, competition with large chain grocery stores, and taxes and regulations.

Conclusions

Consumers do not protect fresh beef products from temperature abuse during vehicular transport from retail to residence. In twelve years, the habitual use of an insulated product to protect temperature dependent foods has increased from 7.0 % to 8.2 %, a respective increase of only 1.2 %. Regardless of increased consumer awareness of food from farm to plate, the study revealed there is still 91.8 % chance a food could be transported from retail to residence without temperature protection. This is concerning as this period of time is a small portion of the consumer cold chain. Additionally, the present study found consumers will continue shopping in a retail food location up to an hour with a fresh beef product left sitting in the cart or basket. Upon checkout, most consumers will place a fresh beef product in the rear seat and floor or trunk or cargo space of the vehicle. Furthermore, 25.8 % of consumers will run additional errands with fresh beef products left sitting in the vehicle for greater than 60 minutes. An insulated bag is most commonly used for temperature abuse protection. Notably, the questionnaire revealed age, sex, ethnicity, and attained education directly influenced fresh beef handling behavior in a retail food location and during vehicular transport to residence ($P < 0.05$). Therefore, the results indicate the continued need for impactful consumer outreach and direct research of handling behaviors for meat.

Table 1. Frequency distribution of age of respondents.

Age	Number of Consumers	Percent
19 to 24 years old	189	12.7
25 to 34 years old	406	27.4
35 to 44 years old	303	20.4
45 to 54 years old	273	18.4
55 to 64 years old	211	14.2
64 or older years old	102	6.9
Total	1,484	100.0

Results from electronic questionnaire distributed by web-based platforms.

Table 2. Frequency distribution of sex type of respondents.

Sex	Number of Consumers	Percent
Male	346	23.3
Female	1,138	76.7
Total	1,484	100.0

Results from electronic questionnaire distributed by web-based platforms.

Table 3. Frequency distribution of ethnicity of respondents.

Ethnicity	Number of Consumers	Percent
Caucasian	1417	95.5
Hispanic or Latino	27	1.8
African American	5	0.3
Native American or American Indian	14	0.9
Asian or Pacific Islander	7	0.5
Other	14	0.9
Total	1,484	100.0

Results from electronic questionnaire distributed by web-based platforms.

Table 4. Frequency distribution of education of respondents.

Level	Number of Consumers	Percent
Less than high school degree	3	0.2
High school degree or equivalent	73	4.9
Some college but no degree	248	16.7
Technical certificate	34	2.3
Associate degree	110	7.4
Bachelor degree	537	36.2
Graduate degree	479	32.3
Total	1,484	100.0

Results from electronic questionnaire distributed by web-based platforms.

Table 5. Frequency distribution of time of day grocery shopping occurs.

Time Period	Number of Consumers	Percent
Morning (5:00 a.m. to 11:59 a.m.)	298	20.1
Afternoon (Noon to 4:59 p.m.)	462	31.1
Evening (5:00 p.m. to 8:59 p.m.)	696	46.9
Night (9:00 p.m. to 4:59 a.m.)	28	1.9
Total	1,484	100.0

Results from electronic questionnaire distributed by web-based platforms.

Table 6. Frequency distribution of time upon fresh beef product placement in cart until checkout.

Time Period	Number of Consumers	Percent
5 minutes or less	133	9.0
6 to 10 minutes	471	31.7
11 to 20 minutes	630	42.5
21 to 30 minutes	216	14.6
31 to 60 minutes	34	2.3
Total	1,484	100.0

Results from electronic questionnaire distributed by web-based platforms.

Table 7. Frequency distribution of time required returning to residence from the grocery store.

Time Period	Number of Consumers	Percent
10 minutes or less	697	47.0
11 to 20 minutes	484	32.6
21 to 30 minutes	211	14.2
31 to 59 minutes	76	5.1
60 to 120 minutes	16	1.1
Total	1,484	100.0

Results from electronic questionnaire distributed by web-based platforms.

Table 8. Frequency distribution of consumers running errands with fresh beef products left in vehicle.

Frequency	Number of Consumers	Percent
Always	5	0.3
Frequently	19	1.3
Occasionally	359	24.2
Never	1,101	74.2
Total	1,484	100.0

Results from electronic questionnaire distributed by web-based platforms.

Table 9. Frequency distribution of time fresh beef product is left in vehicle while completing an errand[1].

Time Period	Number of Consumers	Percent
5 minutes or less	77	20.1
6 to 10 minutes	126	32.9
11 to 20 minutes	106	27.7
21 to 30 minutes	56	14.6
31 to 60 minutes	16	4.2
Greater than 60 minutes	2	0.5
Total	383	100.0

[1]: excludes respondents who selected ‘Never’ in Table 8.

Results from electronic questionnaire distributed by web-based platforms.

Table 10. Frequency distribution of purchased fresh beef product placement in vehicle during transport.

Location	Number of Consumers	Percent
Front (including seat and floor)	170	11.5
Rear (including seat and floor)	627	42.3
Trunk or Cargo Space	674	45.4
Bed of Pickup Truck	13	0.8
Total	1,484	100.0

Results from electronic questionnaire distributed by web-based platforms.

Table 11. Frequency distribution of use of an insulated product to transport fresh beef products.

Frequency	Number of Consumers	Percent
Always	121	8.2
Frequently	190	12.8
Occasionally	347	23.4
Never	826	55.7
Total	1,484	100.0

Results from electronic questionnaire distributed by web-based platforms.

Table 12. Frequency distribution of type of insulated product used to transport fresh beef products in vehicle[1].

Type	Number of Consumers	Percent
Insulated Bag	479	72.8
Personal Size (14.8 quart) Cooler	67	10.2
Medium (40 quart) Cooler	80	12.2
Large (70 quart) Cooler	28	4.3
Extra Large (100 quart) Cooler	4	.6
Total	658	100.0

[1]: excludes respondents who selected ‘Never’ in Table 11.

Results from electronic questionnaire distributed by web-based platforms.

Table 13. Frequency distribution of brand of insulated product used to transport fresh beef products in vehicle[1].

Brand	Number of Consumers	Percent
Coleman®	108	16.5
YETI®	47	7.2
Igloo®	92	14.0
Other	409	62.3
Total	656	100.0

[1]: excludes respondents who selected ‘Never’ in Table 11.

Results from electronic questionnaire distributed by web-based platforms.

Table 14. Demographic influence on fresh red meat handling behaviors during vehicular transport using chi-square analysis[1].

	Handling Behavior		
Demographic	Time prior to checkout and return to residence	Placement in vehicle	Insulated product usage
Age	*	*	*
Sex	*	*	*
Ethnicity	*	-	-
Education	*	-	-

[1]: Based on 1,484 responses.

*: P<0.05

Results from electronic questionnaire distributed by web-based platforms.

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CHAPTER IV: Evaluation of Consumer Handling Behaviors on Temperature, Fresh Beef Quality Characteristics, and the Implications on Palatability during Transfer from Retail Case and Time Spent in Cart.

Abstract

The initial interaction between the consumer and the fresh beef product within the retail case and food retailer drives purchase and perceived palatability (Killinger et al., 2004; Savell et al., 1989). There has not been published research to evaluate the effect of temperature abuse during shopping time from case to check-out in a retail food location and subsequent impacts on palatability. Therefore, the objective was to determine the rate at which fresh beef products increase in temperature upon placement in cart or basket at retail locations, and subsequent effects on palatability and consumer appeal. Upon removal from the retail display case and placement in cart with average internal temperatures of 1.48 °C, average time needed to exceed an internal temperature of 4.4 °C in over-wrap packaged ground beef was 49 minutes given the retail environmental temperature of 21.2 °C. At minute 10, 20, 30, 60, and 120, the respective average internal temperatures were 1.58 °C, 2.12 °C, 2.86 °C, 5.25 °C, and 9.0 °C. Time in cart impacted colorimetric values, surface discoloration, and chroma ($P \leq 0.0004$). No difference in purge or off-odor was seen between control, 10 minute, 20 minute, 30 minute, and TTF samples. Time in cart did not alter shear force values ($P = 0.5334$). Malondialdehyde determinations indicative of lipid oxidation increased numerically as time in cart increased. Time influenced juiciness ($P \leq 0.0028$) and off-flavor intensity ($P = 0.0030$) but had no impact on cohesiveness ($P = 0.8303$) or beef flavor intensity ($P = 0.3656$). Temperature abuse during transport from case to check-out in a retail food location could negatively impact palatability and color in fresh meat given detrimental transport conditions.

Introduction

The retail display case symbolizes the beginning of the consumer cold chain experience. The initial interaction between the consumer and fresh beef product within the retail case drives purchase and perceived palatability (Killinger et al., 2004; Savell et al., 1989). Product shelf-life and color appeal can be readily influenced by the display case characteristics (Steele et al., 2016; Rogers et al., 2014; Martin et al., 2013; Jeremiah and Gibson, 2001). Temperature is one of the most impactful characteristics related to the retail display case. High storage temperatures produce detrimental effects on color and retail appearance as well as negative shelf-life properties resulting from microbial proliferation and lipid oxidation (Martin et al., 2013; Jeremiah and Gibson, 2001). The retail display case is often described as the weakest link in the industry cold chain due to inconsistent storage conditions. Moreover, when the aforementioned inconsistencies are combined with improper consumer handling behaviors, temperature abuse is inevitable.

To date, no published research has evaluated the interaction between the consumer and the period of time a product is selected from retail display case, subsequently placed in a cart, and handled until checkout. Therefore, the current study sought to investigate consumer behaviors regarding fresh red meat product handling during the period of product transfer from the retail display case into a cart until checkout and the subsequent effect on palatability and meat quality characteristics resulting from time time spent in the cart. The results from this study will provide consumers with direct insight into improper handling behaviors and the subsequent effects on color acceptability, tenderness, juiciness, and flavor.

Materials and Methods

Sample Preparation

Grind sources for the study included: USDA Select Beef Chuck, Shoulder Tender (IMPS # 114F), and Beef Bottom Round (Gooseneck) (IMPS # 170). The total meat block weighed approximately 20.4 kg, comprised of 16.3 kg Gooseneck and 4.1 kg Shoulder Tender, respectively. Prior to processing, grind sources were trimmed of visual defects, and fabricated into 5.08 cm x 5.08 cm chunks for uniformity. The grind sources were then placed in a mixer grinder (Model AMFG 48; Biro Manufacturing Company, Marblehead, OH, USA) fitted with a 0.635 cm plate and mixed for approximately 1 min prior to the initial course grind step. Debris was then removed from the auger and plate. After the beef was course grind, the plate was changed to a 0.3175 cm plate and reground to fine particle size.

Following processing, ground beef loaves (n = 21) weighing approximately 816.4 g were placed onto 4D Styrofoam trays (Cryovac, Duncan, SC) with absorbent diapers, and over-wrapped with oxygen-permeable polyvinyl chloride film (O_2 transmission = 23,250 mL/m2/24 h, 72 gauge). Samples were then stored in a walk-in type cooler at 2 ± 2 °C for 24 h prior to treatment.

Proximate Analysis of Raw Material

Raw material moisture, protein, and fat content were determined using a FOSS FoodScan (FOSS Analytical A/S, Foss Allé 1, DK-3400 Hillerǿd, DK) with ISIscan software. Three random samples were collected from the ground meat block and assessed in duplicate. Once homogenized, a sample cup (D:140 mm, 14 mm height (FOSS Analytical A/S, Foss Allé 1, DK-3400 Hillerǿd, Denmark)) was filled completely with the sample, weighing approximately 250 g. Subsequently, the sample was hand-packed to ensure no air pockets or gaps existed. A check cell procedure was run to calibrate the device. Analyses were performed using a ground meat products calibrated program. Following each analysis, the sample cup was cleaned to minimize error and contamination.

Experimental Design and Treatment

Ground beef was chosen as the raw material source. The raw material source was comprised of 68.4 % moisture, 17.5 % fat, and 12.9 % protein. The experimental parameters were determined by the findings observed in Chapter III. The experimental design included one temperature (21.2 °C room temperature) over six time treatments (0 - control, 10, 20, 30, 360 minutes, and minutes to greater than 4.4 °C internal temperature- denoted as TTF). Ground beef samples (n =21) were allotted to the following time treatments: 0 min - control (n = 5), 10 min (n = 3), 20 min (n = 3), 30 min (n = 3), 360 min (n = 2), and TTF (n = 5).

To begin experimentation, all packaged ground beef samples, excluding 0 min - control, were removed from a retail rack with a display temperature of 2 ± 2 °C, and placed in a basket with an average environmental temperature of 21.2 °C to simulate a retail location. Internal temperature logging occurred continuously in 1 min intervals during the entire experiment. Immediately after the respective time treatment was completed, surface temperature was assessed on control, 10 min, 20 min, 30 min and TTF samples.

Meat color evaluation, purge percentage, and off-odor were assessed on each sample including the 360 min treatment samples both pre-treatment and post-treatment. Allotted to a 10 d consumer appeal assessment, two samples from the control and TTF treatments (n = 4 total) were removed, and immediately placed in a walk-in type cooler at 2 ± 2 °C upon treatment completion. Post-treatment, respective samples (n = 17 total with 0 min = 3, 10 min = 3, 20 min

= 3, 30 min = 3, TTF = 3, 360 min = 2) were then divided into three portions weighing approximately 272.1 g, and randomly assigned to three analyses (1. thiobarbituric acid reactive substances, 2. cook loss and Allo-Kramer shear force, 3. sensory evaluation). Sample portions were then vacuumed packaged in oxygen permeable bags, and held at 2 ± 2°C until assessment.

Temperature

Environment

Temperature monitors (Model TempTale4; Sensitech Inc., Beverly, MA, USA) coupled to a PC management program (Model TempTale Manager Desktop 7.4; Sensitech Inc., Beverly, MA, USA) were used for environmental temperature assessment. Prior to recording, monitors were programmed to record in degrees Celsius in 1 min intervals. Monitors (n = 2) were placed in the retail-simulation location to record environmental temperature during the experiment. Following the experiment, data from each monitor, respectively representing time treatments, were downloaded to the TempTale Manager Desktop program and subsequently transferred to a spreadsheet program (Model Microsoft Excel; Microsoft, Redmond, VA, USA) for statistical analysis. Results were interpreted by subject field personnel.

Internal

Temperature monitors (Model TempTale4; Sensitech Inc., Beverly, MA, USA) coupled a PC management program (Model TempTale Manager Desktop 7.4; Sensitech Inc., Beverly, MA, USA) were used for internal sample temperature analysis. Prior to treatment, monitors were programmed to record in degrees Celsius in 1 min intervals. Approximately 7 samples (n = 5 TTF samples; n = 2 360 min samples) were probed in the geometric center for temperature recording during the experiment. Following the experiment, data from each monitor at each time treatment, were downloaded to the TempTale Manager Desktop program and subsequently transferred to a spreadsheet program (Model Microsoft Excel; Microsoft, Redmond, VA, USA) for statistical analysis. Results were interpreted by subject field personnel.

Surface

An infrared thermometer (Model IRT207 Heat Seeker 8:1 mid-range; General Tools & Instruments LLC., Secaucus, NJ, USA) was used to assess surface temperature. Assessment was performed approximately 2.54 cm above the geometric center and anterior as well as posterior locations for a total of 3 readings, given each respective over-wrapped ground beef sample. Data was recorded for further statistical analysis.

Meat Color Evaluation

Following the American Meat Science Association's visual color-scoring scales (AMSA, 2012), subjective color values (Ground Meat Initial Color, Ground Meat Color, Ground Product Display Discoloration) were evaluated on the ground beef samples given the assigned treatment. Given the respective descriptive visual-scale, trained panelists at Auburn University (n = 3) evaluated meat color changes on scale of 1 to 8; where 1 = very light red, very bright red; 4 = slightly bright red, slightly dark red; and 8 = dark red or tan.

Objective color values (L*, a*, b*) were evaluated on ground beef samples during treatment times using a Hunter Miniscan XE Plus (Model MSXP-4500C; Hunter Laboratories, Reston, VA, USA). This study utilized illuminant D65, at 10˚ observance angle and a 2.54 cm aperture to obtain measurements. The colorimeter was calibrated with HunterLab white and black instrument standard tiles. Color analysis was performed in duplicate on each sample for accurate representation, and an average value of L*, a*, and b*, was recorded. Chroma and percent discoloration values were calculated as described in the AMSA Meat Color Measurement Guidelines (AMSA, 2012).

Purge Percentage and Off-odor

Both purge percentage and off-odor were subjectively assessed by trained personnel (n = 3) at Auburn University. Purge percentage was assessed as a whole number on a percentage basis (1 to 100 %) given the weight of the ground beef loaf. Following the American Meat Science Association's 'other scales associated with meat color evaluation' (AMSA, 2012), off-odor was measured on all ground beef samples. Given the respective descriptive off-odor scale, trained panelists at Auburn University (n = 2) evaluated meat off-odor on a scale of 1 to 5; where 1 = no off-odor; 5 = extreme off-odor.

Thiobarbituric Acid Reactive Substances (TBARS)

Ground beef samples allotted for TBARS analysis were thawed at 4 °C for 24 h and followed a modified procedure described by Tarladgis et al. (1960) and performed by Fernando et al. (2003). A 5 g sample was blended in a Waring® commercial laboratory blender with 30 mL of deionized water for 1 min and transferred to a 250 mL distillation tube. The blender cup was washed with an additional 20 mL of deionized water and poured into the same distillation tube. A volume of 2.5 mL of 4 N HCl was added to the mixture, stirred, and distilled at a maximum rate until 25 mL of distillate was collected in a 25 mL volumetric flask. After distillation was complete, 5 mL of distillate was pipetted into a 50 mL pre-sterilized centrifuge tube from VWR® in duplicate, and 5 mL of .02 M 2-thiobarbituric acid in 90% acetic acid was added and vortexed. The caps were tightly capped and heated in a reciprocal shaking boiling water bath (Thermo Scientific Laboratory Services Equipment) for 30 min, and cooled to room temperature. The absorbance was read at 532 nm using a Beckman Coulter® Du® 730 Life Science UV/Vis spectrophotometer. A K-value was calculated using 1,1,3,3-tetraethoxypropane as the standard, and the TBARS readings were recorded by multiplying the absorbance by the K-value of 7.8 (Tarladgis et al. 1960).

Cook Loss and Allo-Kramer Shear (AKS)

Ground beef samples to be used for cook loss and AKS were stored at 2 ± 2 °C for 48 hours. Ground beef patties were cooked on clam-shell-style grills (Calphalon Removable Plate Grill, Caphalon, Perrysburg, OH), preheated to ~177°C and cooked to an internal temperature of 70 °C. Temperatures were monitored with copper constantan thermocouple wire inserted into the geometric center of the patty, and attached to a hand-held Omega data logger HH309A temperature recorder (Omega, Stamford, CT). Cook loss values were determined by weighing patties prior to cooking. After cooking, patties were allowed to cool and were then reweighed to determine percent cook loss. Cooked patties were then covered in aluminum foil, labeled, and chilled at 2 ± 2 °C for 24 h.

Following the American Meat Science Association (AMSA) Research Guidelines for Cookery, Sensory Evaluation, and Instrumental Tenderness Measurements of Meat (2nd ed.) (AMSA, 2015), one strip (2.5 cm wide) was removed from the geometric center of each patty. Each strip was sheared using a TA-XT2i Texture Analyzer shear machine (Texture Technologies Corp., Scarsdale, NY) with a five blade Allo-Kramer shear cell (100 kg load cell) attachment. The shear cell was programmed to be lowered 48.0 mm after detection of resistance. The penetration speed was 3.0 mm/s with a post-test speed of 10.0 mm/s. The assessment was performed in duplicate. Measurements were then averaged for statistical analysis.

Trained Sensory Evaluation

Ground beef samples were held at 2 ± 2 °C for 24 h prior to analysis. Ground beef samples weighing 113.6 ± 0.4 g were pressed into uniform patties. Once the patties reached an internal temperature of 70 ºC based on thermocouple monitoring, they were removed from the grill. Patties were then allowed to rest for 10 minutes before portioning. After resting, each patty was portioned into equal sections (1.27 cm x 1.27 cm x patty thickness). Each sample was randomly assigned a three digit code to ensure no bias, and samples were placed in clear plastic cups with lids. Sample cups were then placed in pans and kept in a warming oven until served to a trained sensory panel, consisting of 8-14 members. Each panelist was given a sample cup containing 1 sample from each ground beef patty for evaluation of initial and sustained juiciness, cohesiveness, beef flavor intensity, and off flavor intensity on a scale of 1 to 8; where 1 = extremely dry, crumbly, bland, and no off-flavor, and 8 = extremely juicy, cohesive, intense, and intense. Panelists evaluated samples in secluded partitioned booths with 250 Lx of red incandescent light. Panelists were also instructed to cleanse their palate with a salt-free saltine cracker and a sip of apple juice before each evaluating each sample. A total of 2 sessions over 2 d (September 2016) were utilized to complete sensory evaluation of 17 total samples, 9 and 8 samples per session, respectively. The sensory evaluation form is presented in Appendix F.

Color Appeal Shelf-life Trial

Following treatment, pre-designated samples (n = 4; 0 min - control and TTF) were immediately placed on a rack in a walk-in cooler held at 2 ± 2 °C for color evaluation over a 10 d period. Every day, starting on d 0, over-wrapped packages were scanned with a Hunter Miniscan XE Plus (Model MSXP-4500C; Hunter Laboratories, Reston, VA, USA), with illuminant D65, at

10˚ observance angle, and a 2.54 cm aperture to obtain measurements. Packaged samples were rescanned every 24 hours. Subsequently, packaged samples were subjectively assessed for meat color and discoloration. The objective and subjective meat color assessments were performed as outlined in the Meat Color Evaluation. Packaged samples were randomly rotated on the rack daily following analysis. Cooler temperature was verified daily.

Statistical Analysis

A completely randomized design was used to conduct these experiments. Statistical analysis was performed with the Proc Mixed procedure in SAS version 9.4 (SAS Inst. Inc., Cary, NC). For all experiments excluding the color appeal shelf-life trial, the independent variable was time. For the color appeal shelf-life trial, day and time were the independent variables. Rep was considered random, and day was treated as a repeated measure. Appropriate two way interactions of day and time were evaluated. In the event that no interactions were observed, main effects were evaluated. Least squares means were separated by using the DIFF procedure. Statistical significance was reported as P-values being < 0.05.

Results and Discussion

Temperature

Internal and Surface

Temperature-dependent foods should be maintained at cold storage temperatures no greater than 4.4 °C due to bacteria proliferation (USDA-FSIS, 2016; FDA, 2013; Jay et al., 2003). Upon removal from the retail display case with average initial temperatures of 1.48 °C, the average time needed to exceed an internal temperature of 4.4 °C in over-wrap packaged ground beef was approximately 49 minutes given the retail environmental temperature of 21.2 °C (Figure 1). At minute 10, 20, and 30, the respective average internal temperatures were 1.58 °C, 2.12 °C, and 2.86 °C (Figure 1); on average, during the first 50 minutes, an initial temperature increase of 0.74 °C was observed every ten minutes. The minute intervals between minutes 30 to 40 and minutes 40 to 50 showed the higher rates of mean internal temperature increase when compared to the initial first 20 minutes.

Per the United States Department of Agriculture- Food Safety Inspection Service (2016), ground beef should not be out at room temperature for more than 120 minutes. Importantly, this study found average internal temperatures of 5.25 °C, 9.0 °C, 12.0 °C, 14.8 °C, and 17.05 °C were observed at 60, 120, 180, 240, and 300, respectively (Figure 2). After 6 hours without refrigeration and held in an environmental temperature of 21.2 °C, over-wrap packaged ground beef samples produced an average internal temperature of 18.8 °C (Figure 2). An average increase of 2.9 °C per hour was observed in this study given an environmental temperature of 21.2 °C. As depicted in Figure 2, the rate of temperature increase appeared to slow per 60 minute interval; average internal temperatures increased most rapidly in the first 120 minutes.

The average surface temperature of the ground beef samples was higher when compared to the internal temperature of the respective samples given an environmental temperature of 21.2 °C (Table 15). Upon removal from the retail display case, average surface temperature initially measured - 0.05 ºC; correspondingly, average temperatures increased to 5.14 °C, 5.57 °C, 8.16 °C, and 9.41 °C at 10, 20, 30, and 49 minutes. The surface temperature reactivity to the extrinsic environment higher temperatures could be due to direct surface area exposure as opposed to the intrinsic insulative properties of the internal surface area. Even with a greater emphasis given to internal temperature measurements in meat products, it is important to pay attention to in-home ground beef handling behaviors such as patty preparation where previous external surfaces may be mixed with internal surfaces.

Meat Quality

Objective and Subjective Meat Color Evaluation

Time effects were observed on L*, a*, and b* values ($P < 0.0001$; $P < 0.0001$; $P = 0.0004$; Table 16). L* values are used to denote white to black with the center being gray; a lower value indicates a darker lean color. As presented in Table 16, ground beef treatment samples held at 21.2 °C for 360 minutes presented the darkest lean color ($P < 0.05$). No L* value differences were observed between control, 10 minute, 20 minute, and 30 minute ground beef treatment samples. Interestingly, TTF samples displayed the highest average numerical value (Table 16). Furthermore, it appeared the ground beef samples became lighter during the first 49 minutes and ultimately became darker at 360 minutes of exposure. Furthermore, a* values are used to determine green and red color in meat such that a positive value will indicate a red color whereas a negative value will indicate a green color. As shown in Table 16, a* value differences were not detected between control, 10 minute, 20 minute, and 30 minute ground beef treatment samples. At TTF, lean color was significantly less red when compared to the control, 10 minute, 20 minute, and 30 minute ground beef treatment samples ($P < 0.05$; Table 16). Ultimately, the least red lean color was seen in the 360 minute ground beef samples ($P < 0.05$; Table 16). The reduction in redness over time could be due a shift from oxymyoglobin to metmyoglobin color properties as described by Bekhit and Faustman in 2005. Positive b* values indicate yellow color while negative values indicate blue color. The lowest numerical b* values presented in Table 16 were seen in the TTF and 360 minute samples, with the 360 minute treatment samples being significantly less yellow than all other samples ($P < 0.05$).

A significant effect of time was seen for both discoloration and chroma ($P < 0.0001$; $P < 0.0001$; Table 16). When compared to all other ground beef treatment samples, the 360 minute samples displayed the least amount of redness and the most discoloration as well as the lowest saturation of the principal hue coupled with the lowest color intensity ($P < 0.05$; $P < 0.05$; Table 16). Additionally, when compared to control samples, TTF samples had significantly more discoloration and did not express bright cherry-red color intensity ($P < 0.05$; $P < 0.05$; Table 16). As a result, consumers may request to exchange the fresh beef product for one that has maintained refrigeration in the display case over the shopping period. Or, upon inspection, the consumer may immediately remove the fresh beef product from the cart and place it on a near shelf without refrigeration.

As shown in Table 17, all treatment samples received the same initial mean subjective color scores and initial mean subjective discoloration scores of 1.00 for each respective scale. Thus, all samples were initially very bright red with no surface discoloration. Per evaluation, the 360 minute samples were the only samples to receive differing post-treatment mean scores when compared to initial mean scores, 6.00 for color and 4.00 for discoloration, per respective scale (Table 17). The 360 minute samples produced a slightly dark red color with modest discoloration. Largely, the subjective color evaluations were in agreement with the objective color evaluations in this study.

Purge Percentage and Off-Odor

As presented in Table 18, ground beef treatment samples held at 21.2 °C for 360 minutes exhibited the greatest mean purge loss at 5.0 %. When compared to control samples, the respective 10, 20, 30 minute, and TTF treatment samples did not show an increase in purge percentage (Table 18). Moreover, off-odor was only detected by trained panelists in the 360 minute samples and assigned a mean numerical score of 5.0 indicating a moderate off-odor (Table 18).

<u>Cook Loss and Allo-Kramer Shear</u>

As shown in Table 19, time had no effect on cook loss percentages or Allo-kramer shear force values for over-wrap packaged ground beef samples held at 21.2 °C ($P = 0.4205$; $P = 0.5334$).

<u>Thiobarbituric Acid Reactive Substances</u>

Thiobarbituric acid reactive substances (TBARS) otherwise described as malondialdehyde equivalents are indicative of the auto-oxidation of unsaturated fatty acids expressed in a sample. Oxidative rancidity negatively impacts beef flavor and overall palatability acceptance by the consumer (Campo et al., 2006). Furthermore, Campo et al. (2006) determined under experimental conditions, a TBARS value of 2.0 could be considered the limiting threshold for the acceptability of oxidized beef. The current study found malondialdehyde, measured in MDA, mg/kg, increased numerically as time increased with the TTF and 360 minute ground beef samples producing significantly higher malondialdehyde determinations when compared to all other treatment samples, 1.68 ± 0.07 MDA, mg/kg and 2.45 ± 0.09 MDA mg/kg, respectively ($P < 0.05$; Table 19). Ground beef research by Martin et al. (2013) noted TBARS values increased as time of exposure increased. However, given the limiting threshold of 2.0 as established by

Campo et al. in 2006, only the 360 minute samples, producing 2.45 ± 0.09 MDA, mg/kg, would be described as unacceptable in terms of palatability (Table 19).

Trained Sensory Evaluation

The effect of time on initial juiciness, sustained juiciness, cohesiveness, and beef flavor intensity and off-flavor intensity are presented in Table 20. Time had a significant effect on initial juiciness ($P = 0.0003$) and sustained juiciness ($P = 0.0028$). Higher numerical values indicated a juicer sample. Time had no effect on cohesiveness or beef flavor intensity. All samples were determined to be slightly crumbly, and either slightly intense or slightly bland. In agreement with the subjective off-odor evaluation and malondialdehyde determinations, panelists determined the 360 minute samples had the highest degree of off-flavor intensity when compared to all other packaged ground beef samples ($P < 0.05$). The TTF samples did not significantly differ in off-flavor intensity when compared to the control samples. Furthermore, these findings are consistent with additional observations by Campo et al. 2006 which showed rancid off-flavor exceeds desired beef flavor in ground beef samples when a TBARS value exceeds 2.28 mg MDA/kg meat.

Color Appeal Shelf-life Trial

An interaction of day x time was observed for L* and a* color values ($P < 0.0001$; $P = 0.0240$; Figure 3; Figure 4). As presented in Figure 3, L* values corresponding to control samples were significantly higher on day 1, day 2, day 3, day 4, and day 5 when compared to the TTF treatment samples ($P < 0.05$). Beginning on day 6 through day 8, 49 minute treatment samples became more white color; whereas, 0 minute samples became more black in color (Figure 3). For both the control and TTF ground beef samples, day 9 and day 10 exhibited values significantly more white samples than day 2 through day 8 and the same as day 1 of the assessment ($P < 0.05$). A similar trend for the subsequent L* value decrease followed by an increase to whiteness was observed by Rogers et al. in 2014. Notably, the TTF ground beef samples produced the respective darkest value on day 5; while the 0 minute ground beef samples produced the respective darkest value on day 7. Thus, samples maintaining an internal temperature less than 4.4 °C were lighter for a longer period of time. As shown in Figure 4, a trend of increasing days resulted in decreased redness values regardless of time, nearly a 16 point decrease in redness value from day 1 to day 10. On day 7, control ground beef samples were more red than 49 minute ground beef samples ($P = 0.05$; Figure 4). Interestingly, between days, the greatest decrease in redness was observed between day 2 and day 3 (Figure 4). Additionally, no interaction of day x time was observed for b* color values ($P = 0.1076$). Time was not significant ($P = 0.6608$) although day was ($P < 0.0001$; Table 21). Day 2 exhibited the highest respective b* value at 20.46 ± 0.30; whereas, day(s) 8, 9, and 10 combined to produce the lowest b* values, 15.36 ± 0.30, 15.92 ± 0.30, and 15.91 ± 0.30, respectively (Table 21). For b* values, the greatest rate of change between days was observed between day 5 and day 6 and subsequently between day 7 and 8 (Table 21). The change is lightness to darkness and redness is directly related to chemical changes from oxymyoglobin to metmyoglobin pigmentation (Aberle et al., 2012). In this study, it appears the duration of time at 21.2 °C was detrimental to metmyoglobin reducing activity and thus accelerated the pigmentation shift to metmyoglobin at a more rapid rate which is in agreement with similar fresh red meat studies (Martin et al., 2013).

An interaction of day and time was observed for surface discoloration ($P < 0.0001$; Figure 5). As shown in Figure 5, a trend of increasing discoloration over day was observed. Additionally, 0 minute ground beef samples displayed less surface discoloration on day 7 and day 8 when compared to 49 minute ground beef samples ($P < 0.05$). No interaction of day x time was observed for chroma values ($P = 0.1479$). Time was not significant ($P = 0.0528$) although day was ($P < 0.0001$; Table 22). Day 1 and 2 had the greatest saturation of the principal hue coupled with the highest color intensity when compared to all other days; while day 9 and day 10 had the least hue saturation and lowest color intensity ($P < 0.05$). Importantly, the greatest decrease in chroma values were observed between day 2 and 3, 5 and 6, and between day 7 and day 8 (Table 22). Previous research has indicated a direct link between length of storage time and ground beef color deterioration due to metmyoglobin, especially in the first 3 days (Garner et al., 2014; Martin et al., 2013).

As shown in Figure 6, an interaction of day x time was observed for subjective color score ($P < 0.0001$). From day 1 to day 10, ground beef lean color changed from very bright red to tan (Figure 6). When compared to control samples, TTF samples produced higher color scores on day 5, 6, 7, and 8 ($P < 0.05$); meaning a darker red lean color. Both control and TTF samples showed a clear shift from very bright red to dull red lean color between day 2 and 3. The greatest color score change for TTF samples was between day 4 and 5; while day 7 and 8 showed the greatest score change for control samples. An interaction between day and time was also observed for subjective surface discoloration scores ($P = 0.0009$; Figure 7. Corresponding with subjective color score evaluations, surface discoloration scores increased as the number of days increased indicating metmyoglobin formation (Figure 7). Likewise, both control and TTF samples demonstrated a substantial increase in surface discoloration between day 2 and day 3; however, TTF ground beef samples exhibited greater surface discoloration than control samples on day 5, day 6, and day 7 ($P < 0.05$; Figure 7). Martin et al. (2013) demonstrated color stability and deterioration is negatively affected by increased storage temperatures. Researchers noted day

5 as undoubted lean unacceptability for all treatment samples in the current study. Importantly, subjective and objective color evaluations are in agreement with this observation.

Conclusions

Once removed from the retail display case and placed in cart, the average time needed to exceed an internal temperature of 4.4 °C in over-wrap packaged ground beef is approximately 49 minutes given a retail environmental temperature of 21.2 °C. Importantly, a ground beef product held at room temperature in a cart for 120 minutes will exceed 4.4 °C, the maximum safe suggested internal temperature during the cold storage of ground beef (USDA-FSIS, 2016). Due to direct exposure to the extrinsic environment, surface temperature exceeded internal temperature more rapidly; 4.4 °C exceeded in less than 10 minutes.

Realistic consumer case to check-out times of 10, 20, 30, and 49 minutes had no impact on objective lightness to darkness or redness when compared to samples with internal temperature maintained at 4.4 °C or less. Nonetheless, when compared to control samples, TTF samples produced more discoloration and did not express bright cherry-red color intensity which could be undesirable to consumers at check-out. Lack of color acceptability could lead to immediate exchange or at worst; the fresh beef product could be placed in an undiscovered unrefrigerated area in the retail location for a considerable amount of time and ultimately discarded.

Time from retail display case to check-out had no impact on fresh beef product purge, off-odor detectability or tenderness given realistic time intervals of 10, 20, 30, and 49 minutes when compared to samples with internal temperature maintained at 4.4 °C or less. However, time in cart directly influenced lipid oxidation. Thiobarbituric acid reactive substances values increased numerically as time increased with the TTF and 360 minute ground beef samples producing significantly higher malondialdehyde equivalents when compared to all other treatment samples. Moreover, trained panelists noted increases in off-flavor intensity in ground beef samples with longer in cart time durations prior to check-out. Time in cart had no impact on ground beef cohesiveness or beef flavor intensity.

Day as opposed to time in cart had the greatest influence on color acceptability shelf-life. Between days, the greatest decrease in objective redness was observed between day 2 and day 3 as demonstrated by a clear subjective color shift from very bright red to dull red lean color. However, the greatest color score change for TTF samples was between day 4 and 5; while day 7 and 8 showed the greatest score change for control samples. Likewise, both control and TTF samples demonstrated a substantial increase in surface discoloration between day 2 and 3; however, TTF ground beef samples exhibited greater surface discoloration than control samples on day 5, 6, and 7. Thus, temperature abused samples have decreased color acceptability over time due to more rapid metmyoglobin development and formation.

Fresh meat product temperature abuse can occur in the cart at a retail food location prior to check-out. Based on the results of this study, fresh beef products should not stay in a cart for longer than 49 minutes in order to maintain an internal temperature below 4.4 °C. Furthermore, fresh beef products devoid of refrigeration for 120 minutes will have exceeded 4.4 °C and are therefore classified as temperature abused. Ultimately, further research is needed to investigate the symbiotic effect of vehicular transport from retail to residence on fresh beef product temperature as well as the effect on tenderness, juiciness, flavor, and color.

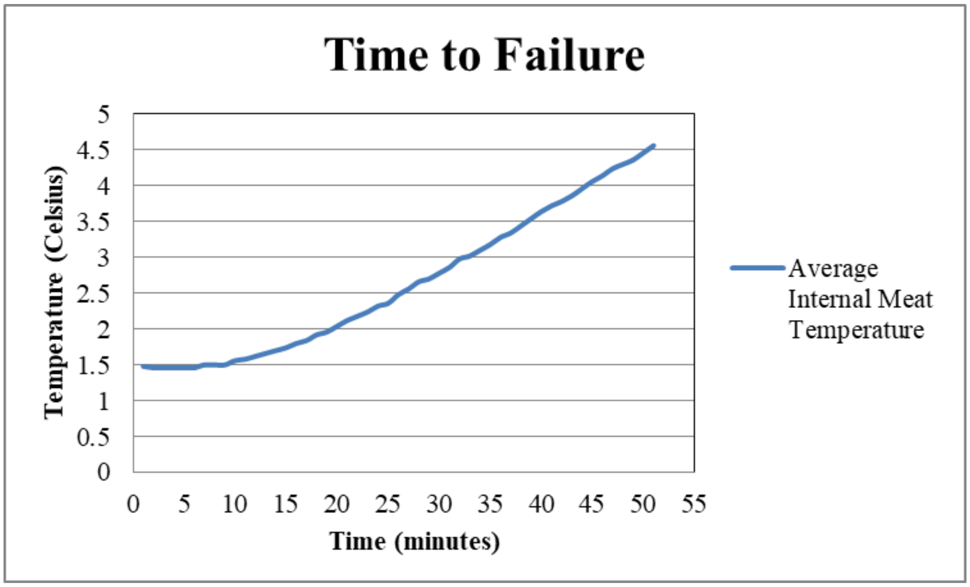

Figure 1. Time needed to exceed the safe internal temperature of 4.4 ºC for over-wrap packaged ground beef placed in cart at a retail location without refrigeration.

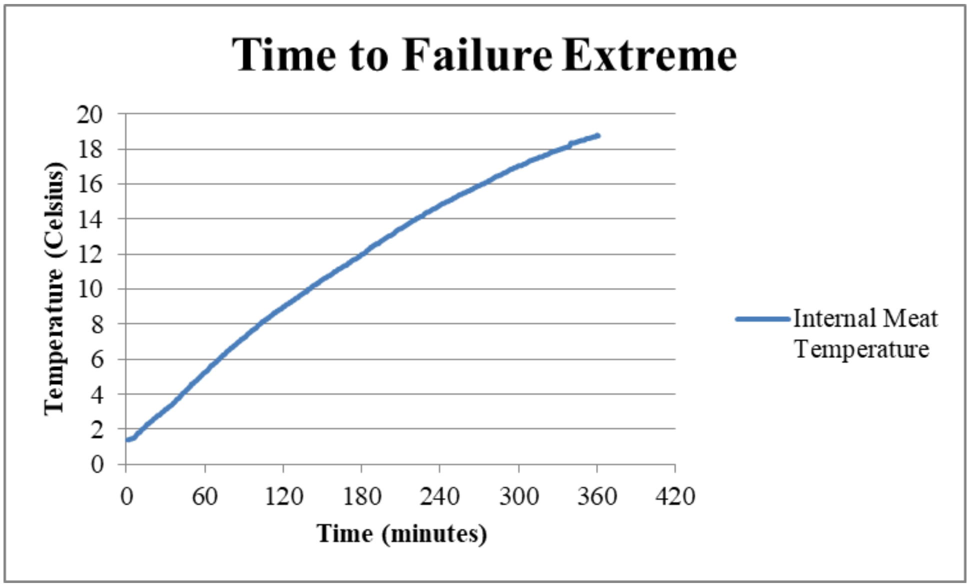

Figure 2. Simple mean temperatures of over-wrap packaged ground beef placed in a cart at a retail location without refrigeration over 360 minutes.

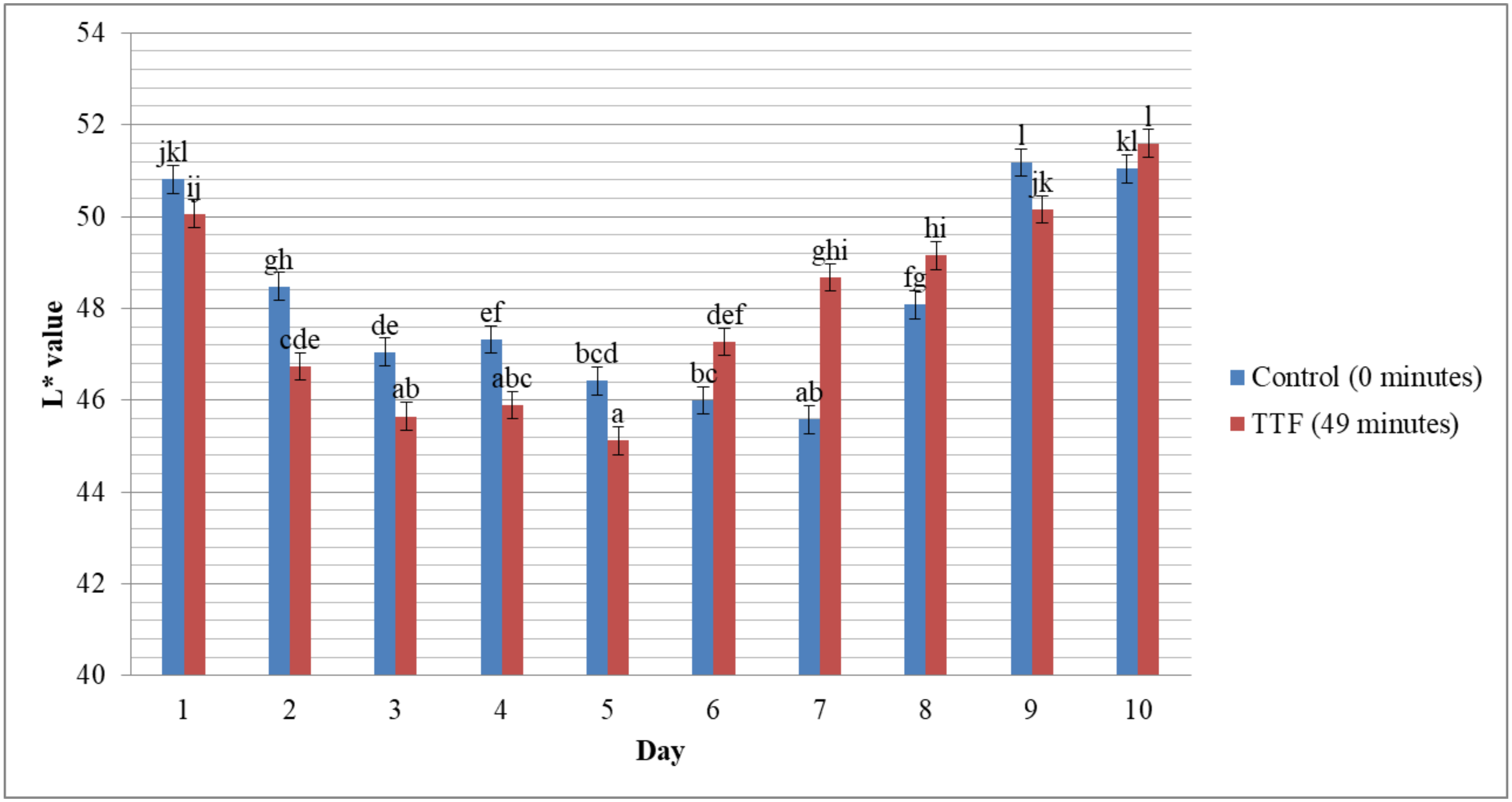

Figure 3. Least squares means of interaction (P<0.0001) of day x time in cart on L* values in over-wrap packaged ground beef.

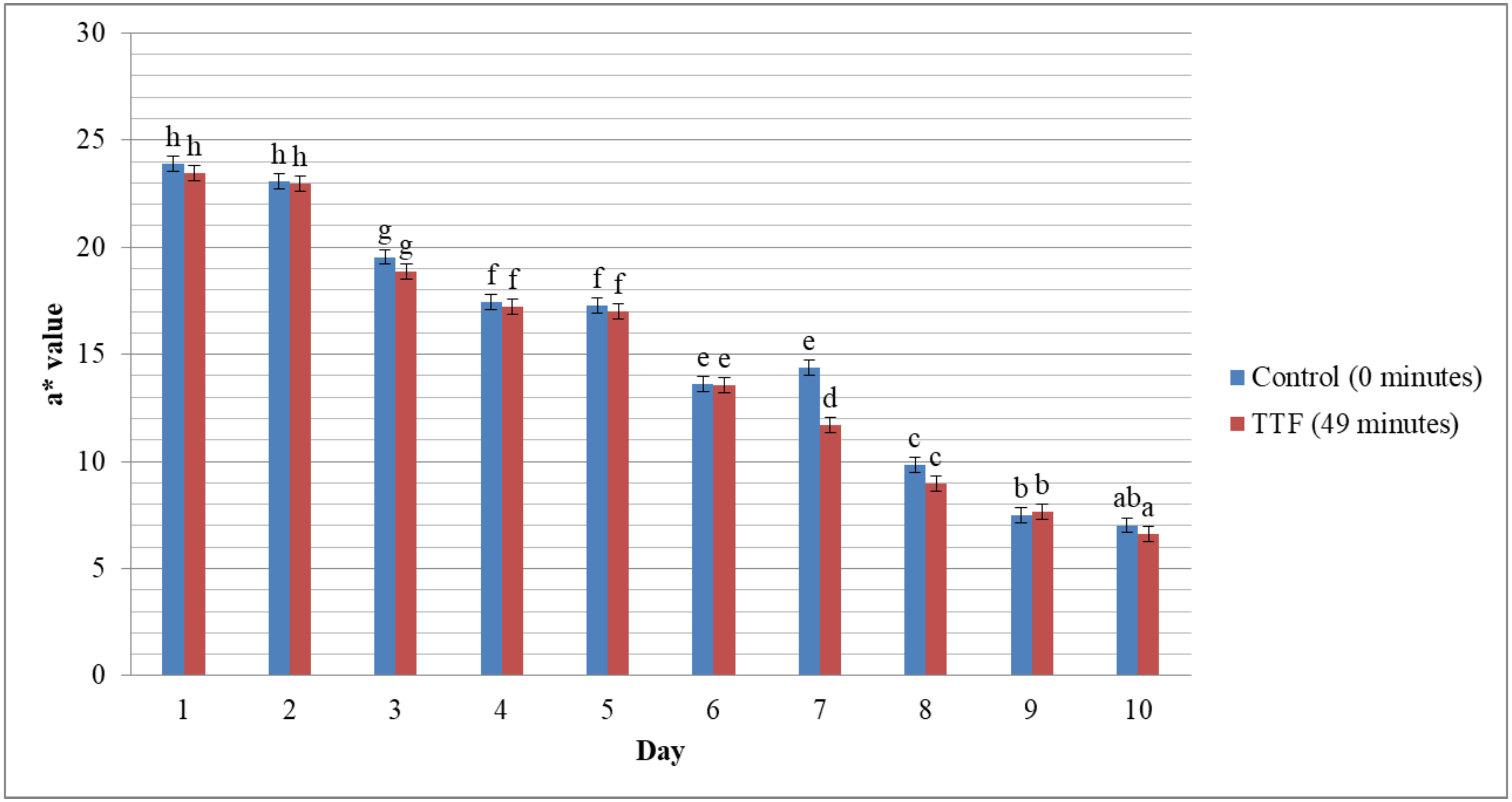

Figure 4. Least squares means of interaction (P=0.0240) of day x time in cart on a* values in over-wrap packaged ground beef.

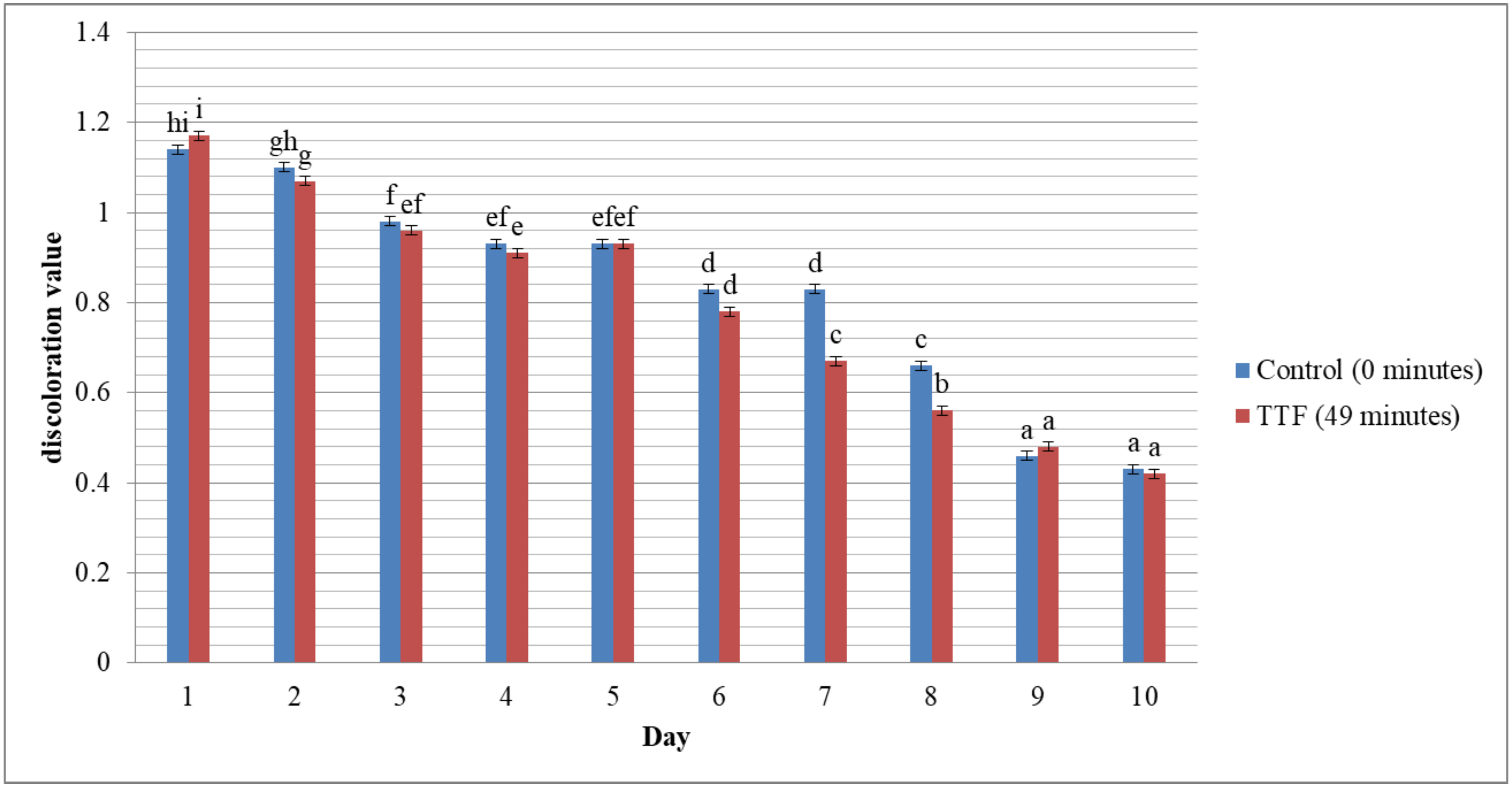

Figure 5. Least squares means of interaction (P<0.0001) of day x time in cart on discoloration values in over-wrap packaged ground beef.

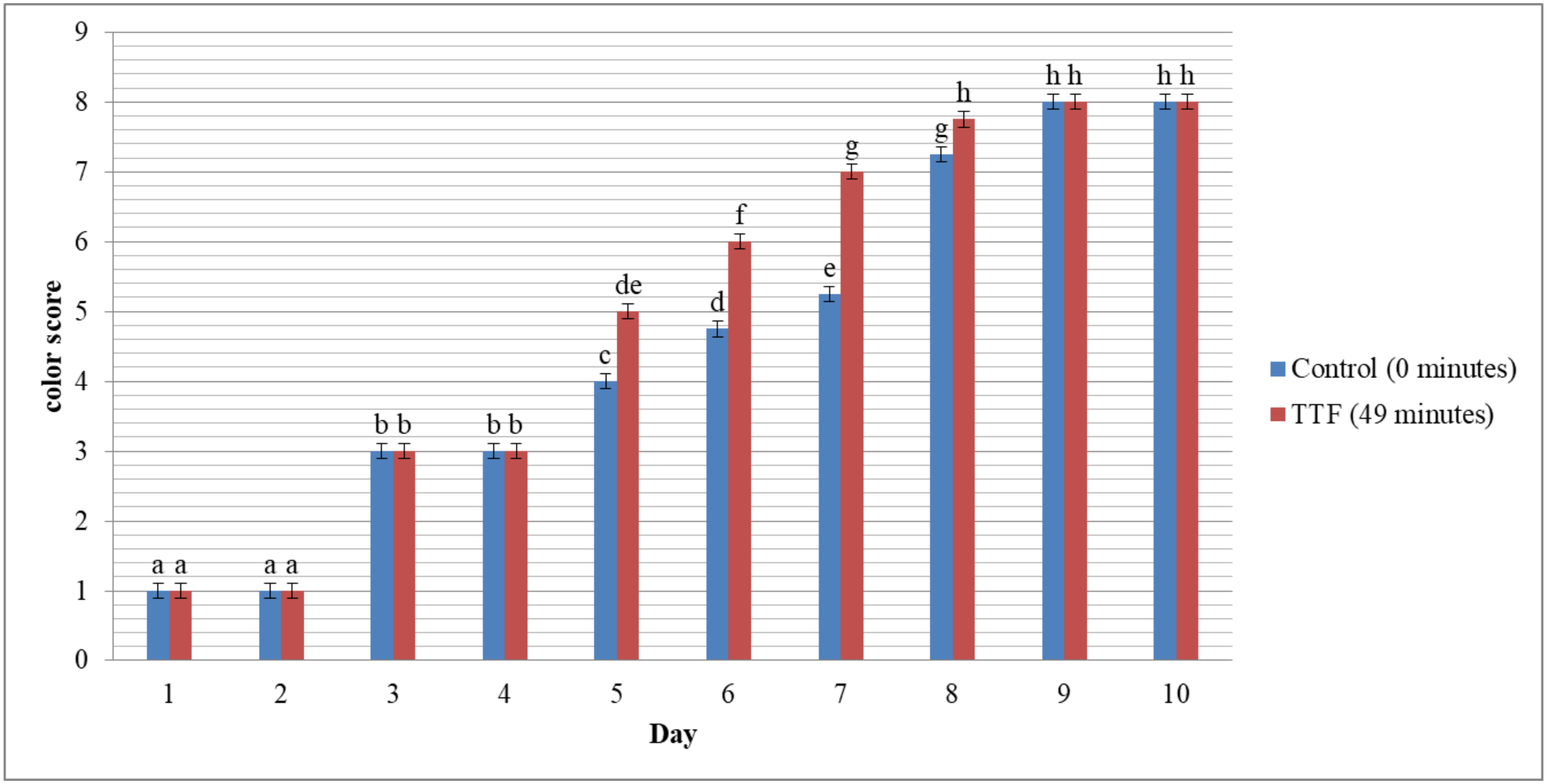

Figure 6. Least squares means of interaction (P<0.0001) of day x time in cart on subjective color scores in over-wrap packaged ground beef.

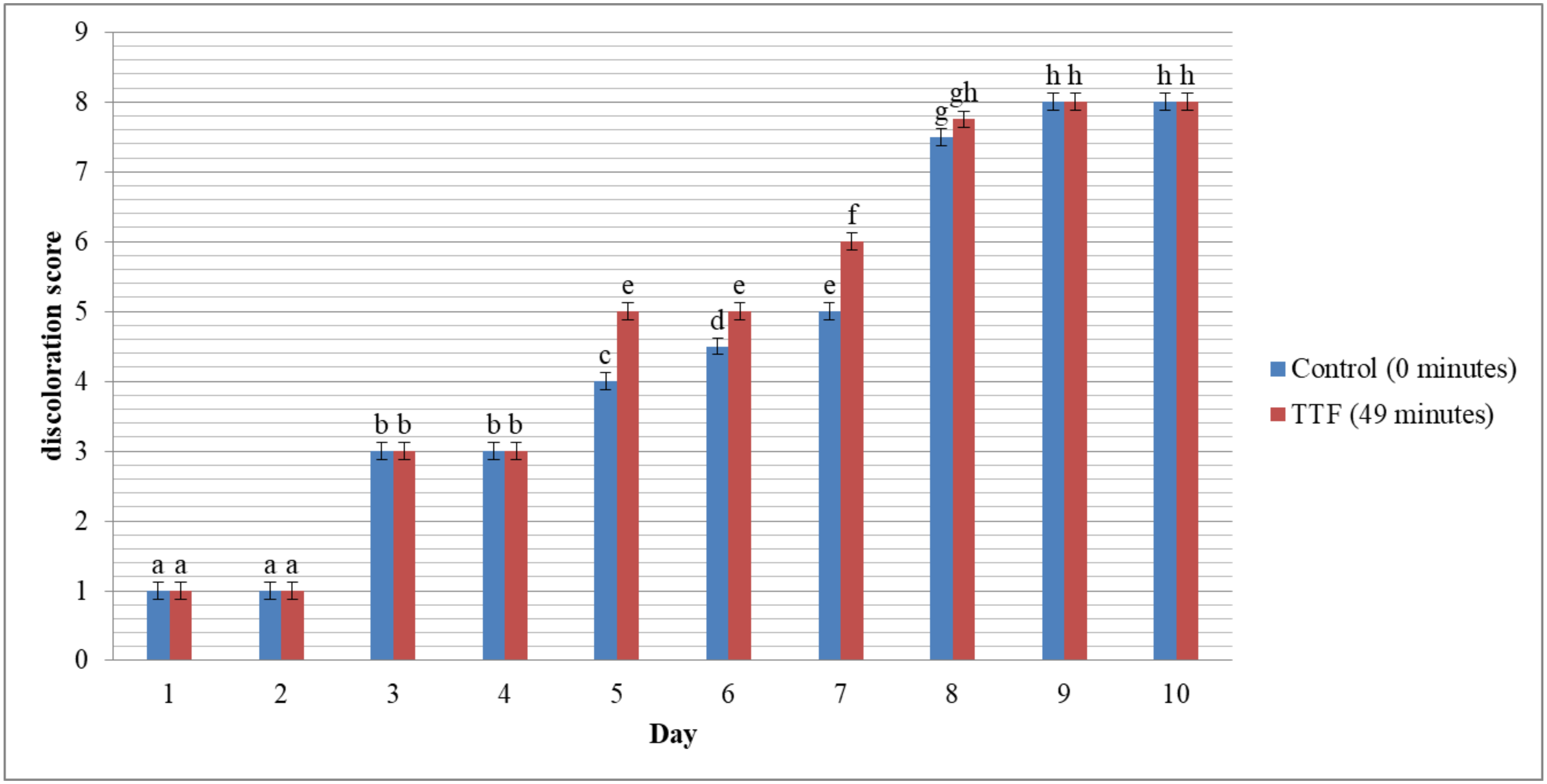

Figure 7. Least squares means of interaction (P=0.0009) of day x time in cart on subjective discoloration scores in over-wrap packaged ground beef.

Table 15. Simple means of surface temperature values for over-wrap packaged ground beef over time product is in cart at a retail location without refrigeration[1].

Trait	Surface Temperature, ºC
Time (minutes)	
Control[2]	-0.05
10	5.14
20	5.57
30	8.16
49	9.41

[1]: Simulated retail environmental temperature of 21.2 ºC.
[2]: Stored in walk in cooler at 2 ± 2 °C.

Table 16. Least square means for colorimetric values and SEM for over-wrap packaged ground beef over time product is in cart at a retail location without refrigeration[1].

Trait	L*	a*	b*	Discoloration[2]	Chroma[3]
Model Significance	$P<0.0001$	$P<0.0001$	$P=0.0004$	$P<0.0001$	$P<0.0001$
Time (minutes)					
Control[4]	47.84±0.45[b]	24.77±0.24[cd]	22.00±0.40[c]	1.12±0.01[b]	46.77±0.58[cd]
10	48.08±0.45[bc]	24.52±0.24[c]	20.83±0.40[bc]	1.17±0.01[bc]	45.35±0.58[bc]
20	47.57±0.45[b]	24.55±0.24[c]	21.72±0.40[c]	1.13±0.01[b]	46.27±0.58[cd]
30	47.03±0.45[b]	25.49±0.24[d]	22.03±0.40[c]	1.15±0.01[bc]	47.53±0.58[d]
49	49.31±0.45[c]	23.74±0.24[b]	19.81±0.40[b]	1.19±0.01[c]	43.56±0.58[b]
360	42.66±0.55[a]	17.14±0.30[a]	18.08±0.49[a]	0.94±0.02[a]	35.23±0.71[a]

[1]: Simulated retail environmental temperature of 21.2 ºC.
[2]: Value = (a*/b*); higher ratios indicate more redness and less discoloration.
[3]: Value = (a*2+b*2)(0.5); higher values indicate more saturation of principle hue.
[4]: Stored in walk in cooler at 2 ± 2 °C.
Values lacking common superscript differ ($P<0.05$).

Table 17. Simple means for subjective color and discoloration for over-wrap packaged ground beef over time product is in cart at a retail location without refrigeration[1].

Trait[2]	Initial Color	Post-treatment Color	Initial Discoloration	Post-treatment Discoloration
Time (minutes)				
Control[3]	1.00	1.00	1.00	1.00
10	1.00	1.00	1.00	1.00
20	1.00	1.00	1.00	1.00
30	1.00	1.00	1.00	1.00
49	1.00	1.00	1.00	1.00
360	1.00	6.00	1.00	4.00

[1]: Simulated retail environmental temperature of 21.2 ºC.
[2]: An eight-point scale was used for the evaluations of color and discoloration (1= very light red, very bright red to 8= dark red, tan).
[3]: Stored in walk in cooler at 2 ± 2 °C.

Table 18. Simple means for subjective off-odor and purge for over-wrap packaged ground beef over time product is in cart at a retail location without refrigeration[1].

Trait[2]	Off-Odor	Purge, %
Time (minutes)		
Control[3]	1.00	1.00
10	1.00	1.00
20	1.00	1.00
30	1.00	1.00
49	1.00	1.00
360	4.00	5.00

[1]: Simulated retail environmental temperature of 21.2 ºC.
[2]: A five-point scale was used for the evaluation of off-odor (1= No off-odor to 5= Extreme off-odor).
[3]: Stored in walk in cooler at 2 ± 2 °C.

Table 19. Least squares means of cook loss, Allo-Kramer shear force, and Thiobarbituric Acid Reactive Substances values and SEM for over-wrap packaged ground beef over time product is in cart at a retail location without refrigeration[1].

Trait	Cook loss, %	AKSF, kg	MDA, mg/kg
Model Significance	P=0.4205	P=0.5334	P<0.0001
Time (minutes)			
Control[2]	29.84 ±0.60	8.84 ±0.48	1.24 ±0.07[a]
10	28.72 ±0.60	8.04 ±0.48	1.38 ±0.07[a]
20	28.46 ±0.60	8.88 ±0.48	1.45 ±0.07[a]
30	28.40 ±0.60	9.33 ±0.48	1.45 ±0.07[a]
49	28.07 ±0.60	8.81 ±0.48	1.68 ±0.07[b]
360	28.86 ±0.74	9.24 ±0.59	2.45 ±0.09[c]

[1]: Simulated retail environmental temperature of 21.2 ºC.
[2]: Stored in walk in cooler at 2 ± 2 °C.
Values lacking common superscript differ (P<0.05).

Table 20. Least squares means for sensory evaluation and SEM for over-wrap packaged ground beef over time product is in cart at a retail location without refrigeration[1].

Trait[2]	Initial Juiciness	Sustained Juiciness	Cohesiveness	Beef Flavor Intensity	Off-Flavor Intensity
Model Significance	P=0.0003	P=0.0028	P=0.8303	P=0.3656	P=0.0030
Time (minutes)					
Control[3]	5.66±0.20[b]	5.33±0.23[bc]	4.61±0.25	4.44±0.21	1.05±0.11[a]
10	5.33±0.20[b]	4.83±0.23[a]	4.72±0.25	4.88±0.21	1.22±0.11[a]
20	4.94±0.20[a]	4.50±0.23[a]	4.38±0.25	4.61±0.21	1.27±0.11[a]
30	5.72±0.20[b]	5.44±0.23[bc]	4.77±0.25	4.77±0.21	1.27±0.11[a]
49	5.61±0.20[b]	5.11±0.23[ab]	4.61±0.25	4.88±0.21	1.33±0.11[a]
360	6.50±0.24[c]	6.00±0.29[c]	4.33±0.31	5.16±0.26	1.83±0.14[b]

[1]: Simulated retail environmental temperature of 21.2 ºC.
[2]: An eight-point scale was used for the evaluations of initial and sustained juiciness, cohesiveness, beef flavor intensity, and off-flavor intensity (1= extremely dry, extremely crumbly, extremely bland, no off flavor to 8= extremely juicy, extremely cohesive, extremely intense beef, and extreme off flavor).
[3]: Stored in walk in cooler at 2 ± 2 °C.
Values lacking common superscript differ (P<0.05).

Table 21. Least squares means of b* values and SEM for over-wrap packaged ground beef over day.

Trait	b*
Model Significance	P<0.0001
Day	
1	20.46±0.30[e]
2	21.15±0.30[f]
3	19.74±0.30[d]
4	18.71±0.30[c]
5	18.39±0.30[c]
6	16.78±0.30[b]
7	17.32±0.30[b]
8	15.36±0.30[a]
9	15.92±0.30[a]
10	15.91±0.30[a]

Values lacking common superscript differ (P<0.05).

Table 22. Least squares means of chroma values and SEM for over-wrap packaged ground beef over day.

Trait	chroma
Model Significance	P<0.0001
Day	
1	44.14±0.50[f]
2	44.16±0.50[f]
3	38.95±0.50[e]
4	36.05±0.50[d]
5	35.54±0.50[d]
6	30.36±0.50[c]
7	30.35±0.50[c]
8	24.77±0.50[b]
9	23.48±0.50[a]
10	22.73±0.50[a]

Values lacking common superscript differ (P<0.05).

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CHAPTER V: Evaluation of Consumer Handling Behaviors on Fresh Beef Temperature, Quality Characteristics, and the Implications on Palatability during Vehicular Transport from Retail to Residence.

Abstract

Previous research has not investigated temperature abuse upon fresh red meat products during vehicular transport from retail location to residence. Temperature dependent foods should not exceed the safe internal temperature of 4.4 °C prior to cooking. The current study sought to investigate the impact of consumer behaviors regarding fresh beef product handling during the period of transport from retail to residence on temperature, color appeal, tenderness, juiciness, and flavor. Results indicated temperature abuse can occur during vehicular transport to residence. Vehicular temperature can exceed environmental temperature during transport. Internal meat temperature will increase regardless of transport conditions or placement location. The use of air conditioning reduced the rate of temperature internal temperature increase. The addition of ice inside a cooler bag will maintain a storage environmental temperature below 7 °C as opposed to 38.5 °C without ice when placed in a temperature abusive vehicular environment. Fresh beef tenderness, juiciness, and flavor can be detrimentally impacted during transport from retail to residence. Ground beef samples placed on the rear seat demonstrated the greatest extent of lipid oxidation given transport without air conditioning or while completing an errand ($P < 0.05$). Vehicular transport conditions impacted both purge and cook loss ($P < 0.05$). Moreover, panelists determined samples transported in the trunk of the vehicle were juicier than samples placed on the rear seat. An effect of vehicular transport to residence on shear force values was observed ($P < 0.05$). No differences were seen in the appearance of myoglobin surface oxidation or the expression of bright cherry-red color intensity across ground beef samples upon arrival at

residence. However, a shelf-life assessment determined color was impacted over time given treatment and location ($P < 0.05$). Results indicate the need for consumer awareness and proper behaviors that will mitigate temperature abuse.

Introduction

Unlike the controlled and highly regulated systematic steps in the production and handling of the fresh red meat product prior to purchase, a consumer's handling behavior cannot be regulated by an outside authority after the product has left the retail setting. Over the past decade in the field of meat science, consumer handling-based research and extension literature have focused on food safety without focusing attention to the consumer's role of affecting palatability (Boyer et al., 2013; Kilonzo-Nthenge et al., 2011; Sofos, 2008; Weddle-Schott, 2007; Godwin and Coppings, 2005; Anderson et al., 2004; Burney et al., n.d.). Studies have agreed that tenderness, juiciness, and flavor are palatability attributes that drive fresh red meat product purchase (Igo et al., 2013; Beriain et al., 2009; Huffman et al., 1996). Research has established that consumer behaviors related to temperature abuse are detrimental to palatability; nonetheless, the emphasis has directly concentrated on in-residence storage, thawing, and cooking methods, not temperature abuse during transport (Grayson et al., 2014; Hergenreder et al., 2013; Lorenzen et al., 1999; Neely et al., 1999; Savell et al., 1999). Notably, the United States Department of Agriculture- Food Safety and Inspection Service (2016) gives only two consumer recommendations for the vehicular transport ground beef: 1. "Plan to drive directly home from the grocery store. 2. You may want to bring a cooler with ice for perishables". The suggested handling behaviors are vague and lack science-based reasoning as to why, how, when, and where a consumer should protect against temperature abuse during vehicular transport from a retail food location.

Previous research has failed to investigate temperature abuse upon fresh red meat products during transport from retail location to residence. The current study sought to investigate the impact of consumer behaviors regarding fresh beef product handling during the period of transport from retail to residence on temperature, color appeal, tenderness, juiciness, and flavor. The results from this study will be used to provide a greater understanding of consumer behavior to the meat industry enabling further focus and development of future technological improvements and marketing strategies for this specific consumer behavior. Additionally, increased consumer awareness could ultimately reduce food waste and enhance sustainability in the United States.

Materials and Methods

Sample Preparation

Grind sources for the study included USDA Select Beef Chuck, Shoulder Tender (IMPS # 114F) and Beef Bottom Round (Gooseneck) (IMPS # 170). The total meat block weighed approximately 22.6 kg, and was comprised of 15.8 kg (IMPS # 170) and 6.8 kg (IMPS # 114F), respectively. Grind sources were trimmed and processed as described in Chapter IV. Ground beef samples (n = 24) were then packaged and stored as denoted in Chapter IV.

Proximate Analysis of Raw Materials

The moisture, protein, fat analysis of the raw materials was performed as described in Chapter IV.

Experimental Design and Treatments

Fresh Beef Product Transport

The 1 d vehicular trial took place in the afternoon on June 28, 2017. Summer was chosen as the designated climatic season due to high environmental temperatures. Ground beef was selected as the raw material source for experimentation. The raw material source was comprised of 63.7 % moisture, 13.6 % fat, and 19.6 % protein. The experimental parameters were determined by the findings observed in Chapter III. A four-door, black sedan with a black leather interior was used for the trial. Ground beef samples (n = 24) were randomly assigned to a vehicular treatment without air conditioning over one time treatment (20 min) or with air conditioning over three possible treatment times (10 min, 20 min, Errand simulation: 20 min on – 10 min off – 10 min on) in two vehicular locations (rear seat or trunk). The without air-conditioning time treatment was performed first followed by the with air conditioning time treatments in conjunction with the errand simulation. Upon turning on the vehicle for the designated air conditioned treatments, the air conditioning unit was turned on with the coolest setting selected to run at a medium fan speed with air blowing through both the floor and dash-panel vents. The air recirculation feature was selected. Internal and environmental temperature logging occurred continuously in 1 min intervals during the entire experiment. Immediately after the respective treatments were completed, surface temperature was assessed on each sample. Meat color evaluation, purge percentage, and off-odor were assessed on each sample both pre-treatment and post-treatment. Post-treatment, respective samples (n = 16 total; 20 min without air conditioning on rear seat = 2, 20 min without air conditioning in trunk = 2, 10 min with air conditioning on rear seat = 2, 10 min with air conditioning in trunk = 2, 20 min with air conditioning on rear seat = 2, 20 min with air conditioning in rear seat = 2, errand simulation on rear seat = 2, and errand simulation in trunk = 2) were then divided into three portions weighing approximately 272.1 g, and randomly assigned to three analyses (1. thiobarbituric acid reactive substances, 2. cook loss and Allo-Kramer shear force, 3. sensory evaluation). Sample portions were then vacuumed packaged in oxygen permeable bags, and held at 2 ± 2°C until assessment. Additionally, a total of 8 ground beef samples (20 min without air conditioning on rear seat = 2, 20 min without air conditioning in trunk = 2, 20 min with air conditioning on rear seat = 2, 20 min with air conditioning in rear seat = 2) were designated for the color appeal shelf-life evaluation.

Insulated Product

In conjunction with the aforementioned temperature abuse trial, generic cooler bags (n = 4; Travelway Group Intl., Saint-Laurent, QC, CA) where placed in the vehicle to assess temperature differences based on location (rear seat or trunk) and use of ice (with or without) in the respective cooler bags. A total of two cooler bags were placed on the rear seat of the vehicle with one cooler bag containing approximately 0.9 kg of ice and one bag containing no ice. Approximately 10 minutes prior to experimentation, the cooler bags selected to contain ice were filled to ensure a pre-chill while the cooler bags devoid of ice were left in the vehicle for exactly 10 min prior to experimentation. During the trial, all treatment cooler bags were left in the vehicle for 20 minutes without air conditioning.

Temperature

Vehicle and Environment

Temperature monitors (Model TempTale4; Sensitech Inc., Beverly, MA, USA) coupled to a PC management program (Model TempTale Manager Desktop 7.4; Sensitech Inc., Beverly, MA, USA) were used for environmental temperature assessment. Monitors (n = 2 per respective location for a total of 8) were placed in the front air vents, front seat, rear seat, and trunk of the vehicle to record internal vehicular temperature prior-to and during the experiment. Additional monitors (n = 2) were placed outside of the vehicle to record the outside environmental temperature. The monitors were programmed, downloaded, and the data were assessed as described in Chapter IV.

Internal

Temperature monitors (Model TempTale4; Sensitech Inc., Beverly, MA, USA) coupled to a PC management program (Model TempTale Manager Desktop 7.4; Sensitech Inc., Beverly, MA, USA) were used for internal sample temperature assessment. Samples designated for errand simulation (n = 2 per location for a total of 4) were probed to obtain samples treatment temperatures located in the rear seat and trunk of the vehicle. Additionally, control samples (n = 2), located in a walk-in cooler held at 2 ± 2 °C, were probed. Finally, samples designated for the 20 min no air conditioning trial (n = 2 per location for a total of 4) were probed to assess temperature differences. The monitors were programmed, downloaded, and the data were assessed as noted in Chapter IV.

Surface

An infrared thermometer (Model IRT207 Heat Seeker 8:1 mid-range; General Tools & Instruments LLC., Secaucus, NJ, USA) was used to assess surface temperature. The surface temperature assessment was performed and analyzed following the outlined procedures in Chapter IV.

Insulated Product

Temperature monitors (Model TempTale4; Sensitech Inc., Beverly, MA, USA) coupled to a PC management program (Model TempTale Manager Desktop 7.4; Sensitech Inc., Beverly, MA, USA) were used for temperature assessment. Monitors (n = 4 total; n = 1 per respective insulated bag) were placed in insulated bags (located in the rear seat and trunk of the vehicle to record temperature during experimentation. The monitors were programmed, downloaded, and the data was assessed as described in Chapter IV.

Meat Color Evaluation

The subjective and objective meat color evaluations were performed as explained in Chapter IV.

Purge and Off-odor

Subjective purge and off-odor assessment was executed as described in Chapter IV.

Thiobarbituric Acid Reactive Substances (TBARS)

Ground beef samples allotted for TBARS analysis followed a modified procedure described by Tarladgis et al. (1960), and performed by Fernando et al. (2003). The experiment was performed in triplicate following the described methods in Chapter IV.

Cook Loss and Allo-Kramer Shear (AKS)

Ground beef patty preparation, thermal processing, and cook loss determination was performed as reported in Chapter IV. Next, following the AMSA Research Guidelines for Cookery, Sensory Evaluation, and Instrumental Tenderness Measurements of Meat (2nd edition, 2015), one strip (2.5 cm wide) was removed from the geometric center of each patty. The shear assessment was then followed as presented in Chapter IV.

Sensory Evaluation

Randomly selected ground beef samples were stored at 2 ± 2 °C for 24 h prior to assessment. Ground beef samples weighing 113.6 ± 0.4 g were pressed into uniform patties. Once the patties reached an internal temperature of 70 ºC based on thermocouple monitoring, they were removed from the grill. Patties were then allowed to rest for 10 minutes before portioning. After resting, each patty was portioned into equal sections (1.27 cm x 1.27 cm x patty thickness). Each sample was randomly assigned a three digit code to ensure no bias, and samples were placed in clear plastic cups with lids. Sample cups were then placed in pans and kept in a warming oven until served to a trained sensory panel, consisting of 8-14 members. Trained sensory evaluation was then performed as described in Chapter IV. A total of 2 sessions (June 2017) were utilized to complete sensory evaluation of 16 total samples, 8 samples per session.

Color Appeal Shelf-life Trial

Following treatment, designated samples (n = 8 total; 2 = 20 min rear with air conditioning, 2 = 20 min trunk with air conditioning, 2 = 20 min rear with no air conditioning, and 2 = 20 min trunk with no air conditioning) were immediately placed on a rack in a walk-in cooler held at 2 ± 2 °C for color evaluation over a 10 d period. Daily, utilizing a Hunter Miniscan XE Plus (Model MSXP-4500C; Hunter Laboratories, Reston, VA, USA) and AMSA's visual-color scoring scales (2012), objective and subjective color assessments were performed as described in Chapter IV for the 10 d trial. Packaged samples were randomly rotated on the rack daily following analysis. Cooler temperature was verified daily.

Statistical Analysis

The experiment was designed as a completely randomized design. Statistical analysis was performed with the Proc Mixed procedure in SAS version 9.4 (SAS Inst. Inc., Cary, NC). The independent variables were treatment (time combined with air-conditioning) and location. The two way interactions of time and location were also included in the model. In the event no interaction was seen, main effects were evaluated. Additionally, for the color appeal shelf-life trial, day, treatment (time combined with air-conditioning), and location were the independent variables; and rep was assigned to the random function while day was assigned to the repeated function. Appropriate three way interactions were evaluated. In the event that no interactions were observed, main effects were evaluated. Least square means were separated by using the DIFF procedure. Statistical significance was reported as P-values being < 0.05.

Results and Discussion

Temperature

Without Air Conditioning

Temperature-dependent foods such should be maintained at cold storage temperatures no greater than 4.4 °C due to bacteria proliferation (USDA-FSIS, 2016; FDA, 2013; Jay et al., 2003). As presented in Figure 8, the trunk environmental temperature was 9.4 °C less than the rear seat and floor at minute 1 of the trial, 43.95 °C versus 34.55 °C respectively. After approximately 5 minutes, the trunk location exhibited a higher temperature than the rear seat; however, at minutes 7 thru 20 over the trial, the trunk was 3.9 °C lower than the rear seat or floor (Figure 8). Additionally, the external environmental temperature averaged 36.9 °C across the entire without air conditioning trial (Figure 8). Importantly, fluctuations in temperatures could have fluctuated due to cloud cover during the 20 minute period. Furthermore, observations noted the rear seat and floor received direct sunlight through the window as opposed to the trunk which reflected the sunlight. The impact of direct sunlight combined with the lack of air movement and heat conductive materials inside the vehicle could explain why the rear seat and floor exhibited higher temperatures than the external environmental temperatures.

Figure 9 demonstrates the mean internal temperatures of over-wrap packaged ground beef with no temperature protection in vehicle without air conditioning when driving from retail to residence in environmental temperatures exceeding 32.22 °C. Ground beef samples placed in the rear seat or floor of the vehicle exceeded a safe internal temperature 4.4 °C in 13 minutes whereas ground beef samples placed in the trunk of the vehicle did not exceed 4.4 °C over the 20 minute trial (Table 23). Moreover, ground beef samples placed in the rear seat or floor of the vehicle produced an average 0.21 °C temperature increase per minute and ultimately had an internal temperature of 6.35 °C at minute 20 as opposed to samples placed in the trunk which exhibited a 0.10 °C per minute internal temperature increase and a minute 20 average internal temperature of 4.4 °C (Figure 9). Therefore, internal temperature increased twice as fast for samples placed in the rear seat or floor when compared to the trunk of the vehicle without air conditioning present. These results are in agreement with the environmental temperature differences between the rear seat and floor and trunk locations. Upon completion of the trial, samples placed on the rear seat of the vehicle had a mean surface temperature of 17.51 °C; while samples placed in the trunk produced a mean surface temperature of 15.04 °C (Table 24). Sample surface temperature exceeded internal temperature. The finding could be due to the surface area interaction with the environment.

With Air Conditioning

Figure 10 presents mean vehicular and environmental temperatures with air conditioning in vehicle when driving from retail to residence. The use of air conditioning during transport resulted in an average temperature decrease of 12.1 °C in the vehicle with decreases of 11.9 °C, 14.35 °C, and 10.05 °C corresponding to the respective front, rear, and trunk locations. At minute 1, the front, rear and trunk locations exhibited initial respective temperatures of 48.55 °C, 47.35 °C, and 41.3 °C followed by respective temperatures of 40.35 °C, 36.55 °C, and 30.1 °C at minute 10 (Figure 10). Lastly, at minute 20, the trunk displayed the lowest temperature at 31.25 °C followed by the rear seat and floor and the front seat and floor, 33.0 °C and 36.65 °C respectively (Figure 10). The greatest decreases in mean location temperatures were observed within the first 10 minutes with the trunk producing the highest rate followed by the rear seat and floor then lastly the front seat and floor. Conversely, from minute 10 to minute 20, the front seat and floor displayed the highest rate of temperature decrease followed by the rear seat and floor and lastly the trunk location. Air conditioning air temperature from the front dash and floor vents decreased over time (Figure 10). Upon starting the vehicle, an initial mean temperature of 30.1 °C was recorded from air passing through dash and floor vents located in the front of the vehicle (Figure 10). Notably, the greatest change in air temperature occurred between minute 1 and minute 2, a respective decrease of 7.6 °C. This rapid change could be the result of the initial blast of hot air from the vents during startup prior to the air being cooled. By minute 10, the mean vehicular air temperature was 14.0 °C ,and ultimately, a mean temperature of 12.4 °C was observed at minute 20 (Figure 10). A mean vehicular air temperature of 16.02 °C was seen over the entire trial. The mean external environmental temperature across the entire trial was 36.25 °C. Initially, the average external environmental temperature was lower than all vehicular locations; however, after 20 minutes, the external environmental temperature exceeded all mean vehicular location temperatures with an observed temperature of 38.7 °C (Figure 10).

Figure 11 reveals the mean internal temperatures of over-wrap packaged ground beef with no temperature protection in vehicle with air conditioning when driving from retail to residence in environmental temperatures exceeding 32.22 °C. In this trial, ground beef samples placed in the rear seat of the vehicle or in the trunk of the vehicle did not exceed an internal temperature of 4.4 °C (Table 23). From minute 1 to minute 10, internal temperature increased at an average rate of 0.035 °C per minute and 0.050 °C per minute for samples placed in the rear seat and trunk locations respectively. The difference between the rear and trunk locations could be attributed to the initial hot air blast from the vents as revealed in Figure 10. Next, from minute 10 to 20, the respective observed mean rate of internal temperature increases for samples located in rear seat and trunk were 0.095 °C per minute and 0.070 °C per minute. Over the entire with air conditioning trial, ground beef samples placed on the rear seat displayed a mean internal temperature increase of 0.065 °C per minute, and at the same time an increase of 0.060 °C per minute was seen in samples located in the trunk. Ultimately, it appears air conditioning buffered the detrimental temperature impact of exposure to direct sunlight on ground beef samples placed on the rear seat. Lastly, at minute 10 and 20, samples placed on the rear seat of the vehicle had respective mean surface temperature of 11.36 °C and 14.68 °C, and mean surface temperatures of 10.16 °C and 14.15 °C when placed in the trunk (Table 24). Sample surface temperature exceeded internal temperature. This result may be due to the surface area interaction with the environment.

Errand Simulation

Figure 12 depicts the means of vehicular and environmental temperatures during an errand simulation (20 minutes with air conditioning- 10 minutes vehicle turned off- 10 minutes with air conditioning) when driving from retail to residence in environmental temperatures exceeding 32.22 °C. At minute 1, the front, rear and trunk locations exhibited initial respective temperatures of 48.55 °C, 47.35 °C, and 41.3 °C followed by respective temperatures of 36.65 °C, 33.0 °C, and 31.25 °C at minute 20 (Figure 12). From minute 21 to minute 30, the period of time when the vehicle was turned off, environmental temperature increased across all locations by an average of 4.9 °C with the greatest increase observed in the rear followed by the front location (Figure 12). While the vehicle was turned off, the vehicular environment regained greater than 50 % of the heat previously reduced from using the air conditioning during the first 20 minutes. Upon restarting the vehicle and turning on the air conditioning from minute 31 to 40, the front and rear locations exhibited mean temperature decreases; 0.635 °C per minute and 0.515 °C per minute, correspondingly. Subsequently, the trunk location mean temperature continued to increase at a rate of 0.290 °C per minute ultimately leading to a highest observed mean temperature per location upon trial completion at 39.15 °C (Figure 12). Regardless of the use of air conditioning during the final 10 minutes of the trial, all vehicular locations exceeded 34.0 °C. The aforementioned location temperature decreases and increases within front and rear vehicular environment followed the recorded air temperature trends collected from vents located in the dash and floor (Figure 12). Upon starting the vehicle, an initial mean temperature of 30.1 °C was recorded from air passing through dash and floor vents located in the front of the vehicle (Figure 12). The greatest change in air temperature occurred between minute 1 and 2, a respective decrease of 7.6 °C. This rapid change could be the result of the initial blast of hot air from the vents during startup prior to the air being cooled. By minute 20, a mean temperature of 12.4 °C was seen (Figure 12). Upon restarting the vehicle after the vehicle was turned off for 10 minutes, an average air temperature of 17.05 was recorded. However, it appeared the air conditioner was more efficient during the final ten minute period of the trial since a rate of air temperature decrease of 0.725 °C per minute was noticed which led to an air temperature of 9.8 °C at minute 40. The mean external environmental temperature across the entire trial was 36.89 °C.

Figure 13 shows displays the average internal temperatures of over-wrap packaged ground beef with no temperature protection in vehicle during an errand simulation when driving from retail to residence in environmental temperatures exceeding 32.22 °C. Ground beef sample internal temperature increased across the entire trial regardless of air conditioning. During the initial 20 minute air conditioning period, packaged ground beef samples placed in the rear seat or in the trunk of the vehicle did not exceed an internal temperature 4.4 °C (Figure 13). Ground beef samples displayed respective mean internal temperature increases of 0.065 °C per minute and 0.060 °C per minute when placed on the rear seat or in the trunk (Figure 13). While the vehicle was turned off for approximately ten minutes without air conditioning in order to simulate the completion of an errand, sample mean internal temperatures increased at rates of 0.36 °C and 0.34 °C per minute given the respective placement on the rear seat or in the trunk. The critical safe internal temperature of 4.4 °C was exceeded by all ground beef samples in both the rear seat and trunk locations during the final ten minutes of the trial when air conditioning was on. Specifically, on average, ground beef samples exceeded the safe internal temperature of 4.4 °C at minute 33 and minute 35 in the rear seat and trunk location respectively (Table 23). Upon completion of the trial, ground beef samples located on the rear seat produced a mean internal temperature of 5.50 °C; whereas samples placed in the trunk exhibited a mean internal temperature of 5.05 °C (Figure 13). Over the trial, samples placed on the rear seat increased at a mean rate of 0.090 °C per minute; and samples located in the trunk increased at a mean rate of 0.082 °C per minute. Even though the rear location of the vehicle had a lower mean environmental temperature than the trunk, the exposure to direct sunlight possibly had a direct impact on the findings. Upon completion of the trial, samples placed on the rear seat of the vehicle had a mean surface temperature of 16.35 °C; whereas, samples placed in the trunk produced a mean surface temperature of 16.97 °C (Table 24). When compared to internal temperature observations, sample surface temperature was higher. This finding could be due to the surface area interaction with the environment.

Insulated Product

Figure 14 displays the mean observed temperatures inside cooler bags with or without ice in vehicular conditions without air conditioning when driving from retail to residence in environmental temperatures exceeding 32.22 °C. The impact of insulated product pre-chilling is made apparent in Figure 14. Regardless of location within the vehicle, the pre-chilled cooler bags containing ice produced an initial mean temperature of 4.0 °C; whereas, the cooler bags left in the vehicle not pre-chilled, without ice had an initial mean temperature of 24.9 °C (Figure 14). Additionally, both cooler bags with ice, regardless of vehicular location, had clearly lower internal mean temperatures than the cooler bags without ice. Upon completion of the 20 minute trial, the pre-chilled cooler bags with ice produced a mean internal temperature of 6.3 °C; while, the cooler bags left in the vehicle without ice had an initial mean temperature of 38.5 °C (Figure 14). Moreover, the pre-chilled cooler bags with ice showed an average temperature increase of 0.115 °C per minute; contrastingly, the cooler bags without ice displayed a mean temperature increase of 0.680 °C per minute (Figure 14). Overall, the cooler bag without ice located on the rear seat produced the highest mean temperatures across the entire trial followed by the cooler bag without ice in the trunk (Figure 14). The results indicate using a cooler bag without ice will not provide an ideal internal environment to protect against temperature. Although fresh meat products are thermally dense and could act as a cooling material for the bag, previous results from this study indicate meat is highly reactive to temperature. Thus, the meat could conduct the heat from the cooler bag. Importantly, this study found using ice in a cooler bag along with pre-chilling produced a cold environment for meat to be placed during transport from retail to residence.

Meat Quality

Objective and Subjective Meat Color Evaluation

Table 25 contains the least squares means for colorimetric values and SEM for packaged ground beef during vehicular transport from retail to residence without temperature protection. No main effects or interactions were observed for the colorimetric values of L*, a*, or b*, which respectively indicate color transitions from white to black, red to green and yellow to blue, respectively ($P \geq 0.0770$). Table 26 exhibits the least squares means of discoloration and chroma values and SEM for packaged ground beef during vehicular transport from retail to residence without temperature protection. Likewise, no significant differences were detected for either main effects of or interaction between treatment and location for discoloration and chroma ($P \geq 0.0561$). Thus, no differences were seen in the appearance of myoglobin surface oxidation or the expression of bright cherry-red color intensity across ground beef samples upon arrival at residence.

All treatment samples received the same initial mean subjective color scores of 1.00 and initial mean subjective discoloration scores of 2.00 which indicated all ground beef samples were initially very bright red with slight surface discoloration (Table 27). After treatment, all samples, except for the 10 minute transport with air conditioning exposure, increased one numerical color unit to a respective 2.0 post-treatment color score which indicated a decrease in redness intensity

(Table 27). Furthermore, samples allotted to the 20 minute transport without air conditioning received a mean post-treatment discoloration score of 3.0, while all other treatments exhibited no increase in surface discoloration when compared to initial assessment (Table 27). The subjective assessment indicated a difference in post-treatment color; nonetheless, all treatment samples were still described as bright cherry red post-treatment. Thus, the descriptive designation is in agreement with objective assessments which indicated samples had a vibrant redness.

Purge Percentage and Off-Odor

Table 28 displays the means for subjective off-odor and purge for over-wrap packaged ground beef transported from retail to residence without temperature protection. The raw materials prior to treatment were deemed to have no off-odor. Post-treatment, all ground beef samples, besides those which were exposed to a 10 minute transport time with air conditioning, received a mean off-odor score of 1.5 as compared to a mean score of 1.0. Per evaluation, the results appear to show an increase in transport time beyond 10 minutes led to an increase in off-odor detectability. This could be due to surface lipid oxidation due to exposure to sunlight as well as possible phospholipid oxidation.

As seen in Table 28, initial purge percentage varied across ground beef treatment samples (Table 28). Regardless, ground beef samples which endured a 20 minute transport period without air conditioning exposure produced the highest respective purge percentage at 0.63 %. The increase in purge percentage could be a direct result of internal and environmental temperature, since the rate of internal temperature increase was high for the aforementioned samples when compared to the other vehicular treatments. Nonetheless, all samples demonstrated an increase in purge post-treatment.

Thiobarbituric Acid Reactive Substances (TBARS)

Thiobarbituric acid reactive substances (TBARS) otherwise described as malondialdehyde equivalents are indicative of the auto-oxidation of unsaturated fatty acids expressed in a sample. Auto-oxidation negatively impacts beef flavor (Campo et al., 2006). Furthermore, Campo et al. (2006) determined under experimental conditions, a TBARS value of 2.0 could be considered the limiting threshold for the acceptability of oxidized beef. Heat creates a large increase of the nonenzymatic lipid oxidation activity of hemoproteins (Eriksson and Vallentin, 1973). The current study found an interaction of treatment x location in vehicle on TBARS values measured in MDA, mg/kg ($P < 0.0001$; Figure 15). Given the most temperature abusive treatments, the errand simulation and 20 minute transport period without air conditioning exposure, ground beef samples placed on the rear seat of the vehicle as opposed to in the trunk, produced higher mean TBARS values comparatively; 1.45 ± 0.02 MDA mg/kg versus 1.15 ± 0.02 MDA mg/kg and 1.09 ± 0.02 MDA mg/kg versus 1.53 ± 0.02 MDA mg/kg, respective of location (Figure 15). No differences were observed in the 10 minute transport with air conditioning exposure treatment; however, samples transported in the trunk for 20 minutes with air conditioning exposure had a higher mean TBARS value when compared to samples placed on the rear seat (Figure 15). Notably, pre-treatment raw materials produced a mean malondialdehyde determination of 0.47 ± 0.02 MDA mg/kg. This is important since initial phospholipid and unsaturated fatty acid content in lean sources impacts the rate of auto-oxidation and rancidity detectability. Given the limiting threshold of 2.0 as established by Campo et al. in 2006, none of the samples exceeded the threshold (Figure 15). Nonetheless, the results are in agreement with the subjective evaluation of off-odor which indicated a trend of slight detectability as both internal and environmental temperature increase within the respective samples leading to accelerated lipid oxidation. Lower storage temperatures are directly associated with lower TBARS values (Utrera et al., 2014). Therefore, lipid oxidation could have occurred on the exposed lean surface of the ground beef samples since mean surface temperatures were higher than observed surface temperatures.

Cook Loss and Allo-Kramer Shear (AKS)

As shown in Table 29, a treatment effect was observed on both cook loss and Allo-Kramer shear force. When compared to all other vehicular transport treatments, ground beef samples exposed to transport for 20 minutes without air conditioning displayed a higher mean respective cook loss percentage and shear force value; 31.52 ± 0.49 % and 15.66 ± 0.60 kg, correspondingly (Table 29). Compared to all other treatments, the respective shear value of 15.66 ± 0.60 kg was approximately 3.25 kg greater than the next highest recorded mean shear for a treatment. Notably, the raw materials prior to treatment portrayed a mean shear force value of 11.65 kg. The high shear value could be due to the inclusion of muscles with high connective tissue content as well as being muscles of locomotion from the chuck and round. Nonetheless, the increase shear force values seen in this study could be due a combination of increased moisture loss and surface lipid degradation that occurred during treatment prior to patty formation ultimately reducing the lubrication effect. Researchers noted an observed increase in cohesive appearance and hardness of the aforementioned samples while shear force measurements were taken. A study conducted by Utrera et al. (2014) determined the extent of temperature induced oxidation on both lipids and proteins negatively impacts water holding capacity and patty hardness in ground beef.

Sensory Evaluation

Table 30 presents the least squares means for initial juiciness, sustained juiciness, and cohesiveness and SEM for packaged ground beef during vehicular transport from retail to residence without temperature protection. Although treatment had no effect on juiciness evaluations, a location effect was seen for both initial and sustained juiciness (Table 30; $P = 0.0120$; $P = 0.0087$). The mean initial juiciness and sustained juiciness scores indicated ground beef samples transported on the rear seat of the vehicle were described as slightly dry while samples placed in the trunk received a designation of slightly juicy. Thus, per panel evaluation, samples transported in the trunk of the vehicle are juicier than samples placed on the rear seat. Neither treatment nor location had an effect on cohesiveness (Table 30; $P \geq 0.6000$).

Beef flavor and off-flavor intensity were not impacted by either treatment or transport location in the vehicle (Table 31; $P \geq 0.1249$). Additionally, no interaction was seen (Table 31; $P \geq 0.1415$). From taste panel analyses, all samples produced a slightly bland beef flavor combined with no detectable off-flavor. The beef flavor and off-flavor intensity assessments are in agreement with the measured lipid oxidation results seen in this study.

Color Appeal Shelf-life Trial

Day ($P < 0.0001$) and location ($P = 0.0480$) were significant sources of variation for colorimetric L* values (Table 32). L* values increased from day 1 up to day 10, 44.86 ± 0.26 versus 46.96 ± 0.26, respectively ($P < 0.05$). This suggests ground beef samples became slightly darker as the number of days increased. Additionally, samples placed on the rear seat appeared whiter than samples placed in the trunk (Table 32; $P < 0.05$). Additionally, both day ($P < 0.0001$) and treatment ($P = 0.0404$) impacted colorimetric a* values (Table 33). Sample redness decreased linearly over the trial ($P < 0.05$). The greatest decreases in colorimetric a* values were seen between days 1 and 2 and days 2 and 3; 3.07 and 2.36, correspondingly (Table 33). From day 1 to day 5, a reduction of nearly 50 % was observed in sample redness. Research by Rogers et al. (2015) observed same reduction percentage of redness over a 10 day period in over-wrap packaged ground beef. The rate of a* reduction decreased over time. Additionally, when compared to samples transported without air condition exposure for 20 minutes, samples transported with air conditioning for 20 minutes yield redder lean (Table 33; $P < 0.05$). Lastly, a decrease in b* values was seen between days 1, day 2, and day 3 (Table 34; $P < 0.05$). However, after day 4, no lean color transition from yellow to blue was shown. In addition to day, both treatment ($P = 0.0009$) and location ($P = 0.0091$) had an effect on colorimetric b* values (Table 34). Samples transported without exposure to air conditioning in the vehicle produced a lower mean b* value than samples exposed to air conditioning for 20 minutes ($P < 0.05$). Similarly, ground beef samples placed on the rear seat demonstrated lower mean b* values than duplicate samples placed in the trunk ($P < 0.05$). Work by Martin et al. (2013) on ground beef storage characteristics determined temperature significantly influenced both colorimetric a* and b* values.

Table 35 exhibits the least squares means of discoloration values and SEM for over-wrap packaged ground beef during vehicular transport from retail to residence without temperature protection. Surface discoloration increased linearly over day ($P < 0.0001$). The greatest increases in colorimetric surface discoloration values were seen between days 1 and 2 and days 3 and 4; 0.12 and 0.10, correspondingly (Table 35; $P < 0.05$). From day 1 to day 10, surface discoloration increased nearly 60 %. Discoloration was significantly affected by treatment (Table 35; $P = 0.0216$). Notably, subjective the discoloration assessment of with or without air conditioning exposure determined the greatest differences between the treatments occurred on day 1 and day 4 with samples transported without air conditioning exhibiting discoloration at a more rapid rate

(Table 36). The effect of day ($P < 0.0001$), treatment ($P = 0.0039$), and location ($P = 0.0169$) on chroma are presented in Table 37. The intensity or perceived strength of redness decreased linearly over the first seven days ($P < 0.05$). The greatest decreases in colorimetric chroma were seen between day 1 and day 2 as well as day 2 and day 3 (Table 37). The findings are in agreement with research by King et al. (2011) which found linear decreases in fresh red meat chroma and associate colorimetric values of a* and b* over day. Furthermore, ground beef samples transported with exposure to air conditioning in the vehicle produced a more intense lean redness than samples transported for 20 minutes without exposure to air conditioning ($P < 0.05$). Likewise, samples transported in the trunk as opposed to the rear seat displayed a higher mean colorimetric chroma value ($P < 0.05$). Ground beef shelf-life work by Martin et al. (2013) determined temperature will significantly impact color saturation of the principle hue. Interestingly, both the transport environment and product placement within the vehicle can influence long-term color appeal. Results of this study indicate the greatest color differences can be seen between day 1 and day 2 followed subsequently by day 3 and day 4. This study also suggests the short-term capacity of fresh beef to mitigate myoglobin oxidation in temperature abusive environments. Data from King et al. (2011) reports a decrease in chroma. Additionally, this work is supported by findings seen by Martin et al. (2013) which determined higher storage temperatures increase the rate of color deterioration and metmyoglobin accumulation which ultimately reduce shelf-life. Thus, transport in temperature abusive vehicular environments directly impacts sustained meat color and ultimate consumer appeal.

Conclusions

Temperature abuse can occur during vehicular transport from retail to residence. Internal vehicular temperature can exceed environmental temperature during meat transport from retail to residence. Given the absence of air conditioning during transport, the trunk of a sedan as opposed to the rear seat of the vehicle maintains a lower temperature which is more suitable to mitigating temperature abuse given direct transport to residence. When transported without air conditioning and an environmental temperature exceeding 32.2 °C, temperature dependent foods such as fresh red meat products placed on the rear seat of the vehicle for transport will exceed the safe minimum internal temperature of 4.4 °C in approximately 13 minutes. Furthermore, running an errand with a fresh beef product left in the vehicle will ultimately induce temperature abuse. While the vehicle was turned off for errand completion, the vehicular environment regained greater than 50 % of the heat previously reduced from using the air conditioning during the first 20 minutes of transport. The errand simulation demonstrated the detrimental effect of increased vehicular temperatures while the vehicle was turned off as opposed to on with air conditioning on the internal temperature of over-wrap packaged ground beef. The critical safe internal temperature of 4.4 °C was exceeded at minute 33 in the rear seat and minute 35 in the trunk location, which was prior to return to residence and subsequent refrigeration or cooking. The use of air conditioning during transport in an environment exceeding 32.2 °C resulted in an average temperature decrease of 12.1 °C in the vehicle with decreases of 11.9 °C, 14.35 °C, and 10.05 °C corresponding the respective front, rear, and trunk locations. Regardless of placement location within the vehicle, over-wrap packaged ground beef transported from retail to residence in 20 minutes or less with exposure to air conditioning did not exceed an internal temperature of 4.4 °C. Importantly, this study showed internal meat temperature will increase regardless of transport conditions. Nonetheless, the use of air conditioning reduced the rate of temperature internal temperature increase. Finally, the use of ice in a cooler bag is crucial since the temperature will increase to 38.5 °C inside the bag without ice present as opposed to being maintained at less than 7.0 °C with ice inside given environmental temperatures exceed 32.2 °C.

The palatability components of tenderness, juiciness, and flavor are all impacted during transport from retail to residence since fresh beef products are most commonly left vulnerable by consumers in temperature abusive vehicular environments. Per assessment, an increase in transport time beyond 20 minutes, regardless of exposure to air conditioning, led to an increase in off-odor detectability. An interaction of treatment x location in vehicle on lipid oxidation values was seen. Given the most temperature abusive treatments, the errand simulation and 20 minute transport period without air conditioning exposure, ground beef samples placed on the rear seat demonstrated the greatest extent of lipid oxidation. Furthermore, the transport of over-wrap packaged ground beef in temperature abusive environments resulted in increased purge. Ground beef samples exposed to transport for 20 minutes without air conditioning produced the highest cook loss percentage at nearly 32 %. Moreover, panelists determined samples transported in the trunk of the vehicle are juicier than samples placed on the rear seat. Lastly, vehicular transport to residence in approximately 20 minutes without air conditioning exposure resulted in a shear value of 15.66 ± 0.60 kg, 3.25 kg higher than the next highest treatment, indicating a tougher meat product when compared to other respective treatment samples.

No differences were seen in the appearance of myoglobin surface oxidation or the expression of bright cherry-red color intensity across ground beef samples upon arrival at residence. However, over time in refrigerated storage, ground beef samples previously transported with exposure to air conditioning in the vehicle produced a more intense lean redness than samples transported for 20 minutes without exposure to air conditioning. Likewise, samples transported in the trunk as opposed to the rear seat displayed a higher mean colorimetric chroma value. Thus, color appeal was not immediately affected after transport, but differences were seen in long-term refrigerated storage.

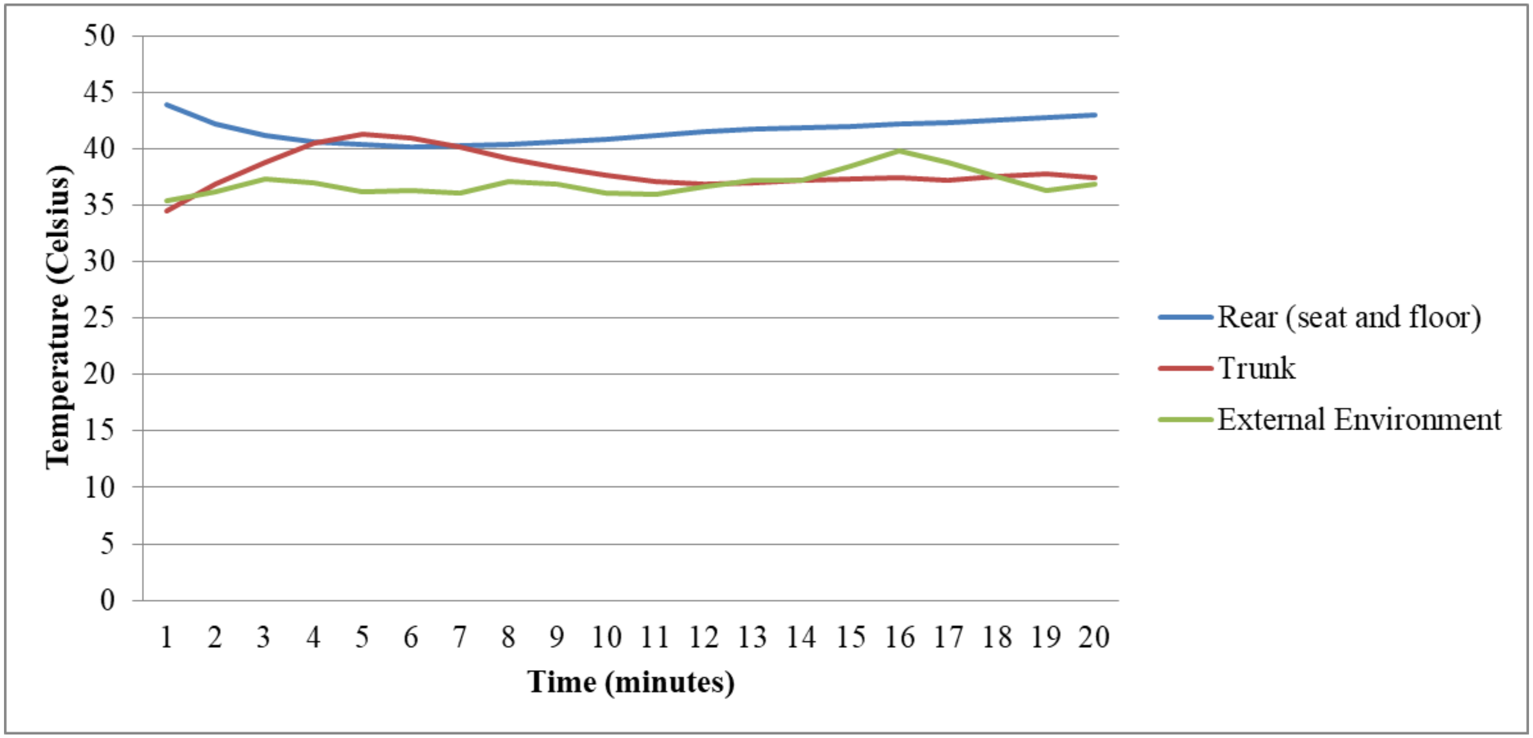

Figure 8. Simple means of vehicular and environmental temperatures without air conditioning in vehicle when driving from retail to residence when environmental temperatures exceeded 32.22 °C.

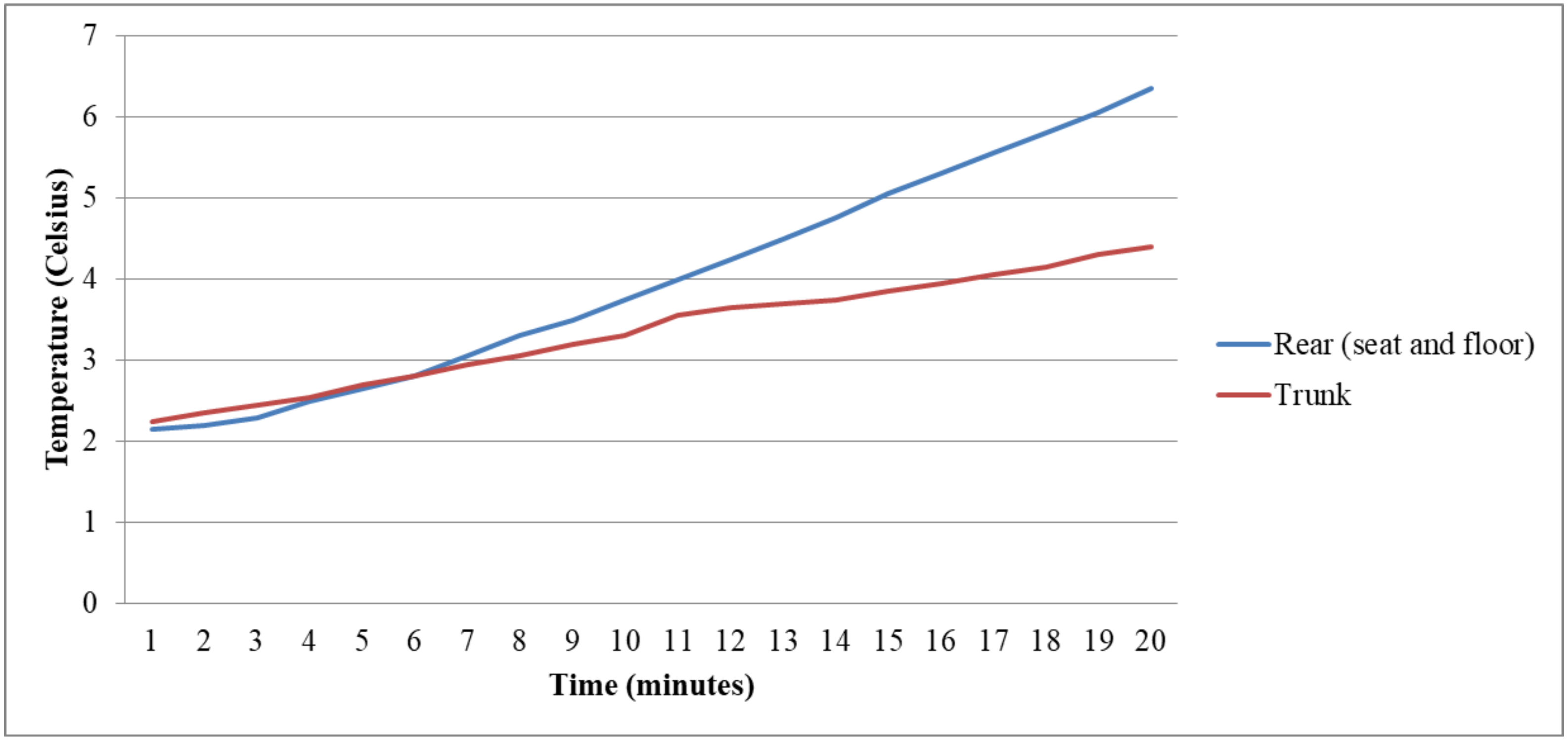

Figure 9. Simple means of internal temperature of over-wrap packaged ground beef with no temperature protection in vehicle without air conditioning when driving from retail to residence when environmental temperatures exceeded 32.22 °C.

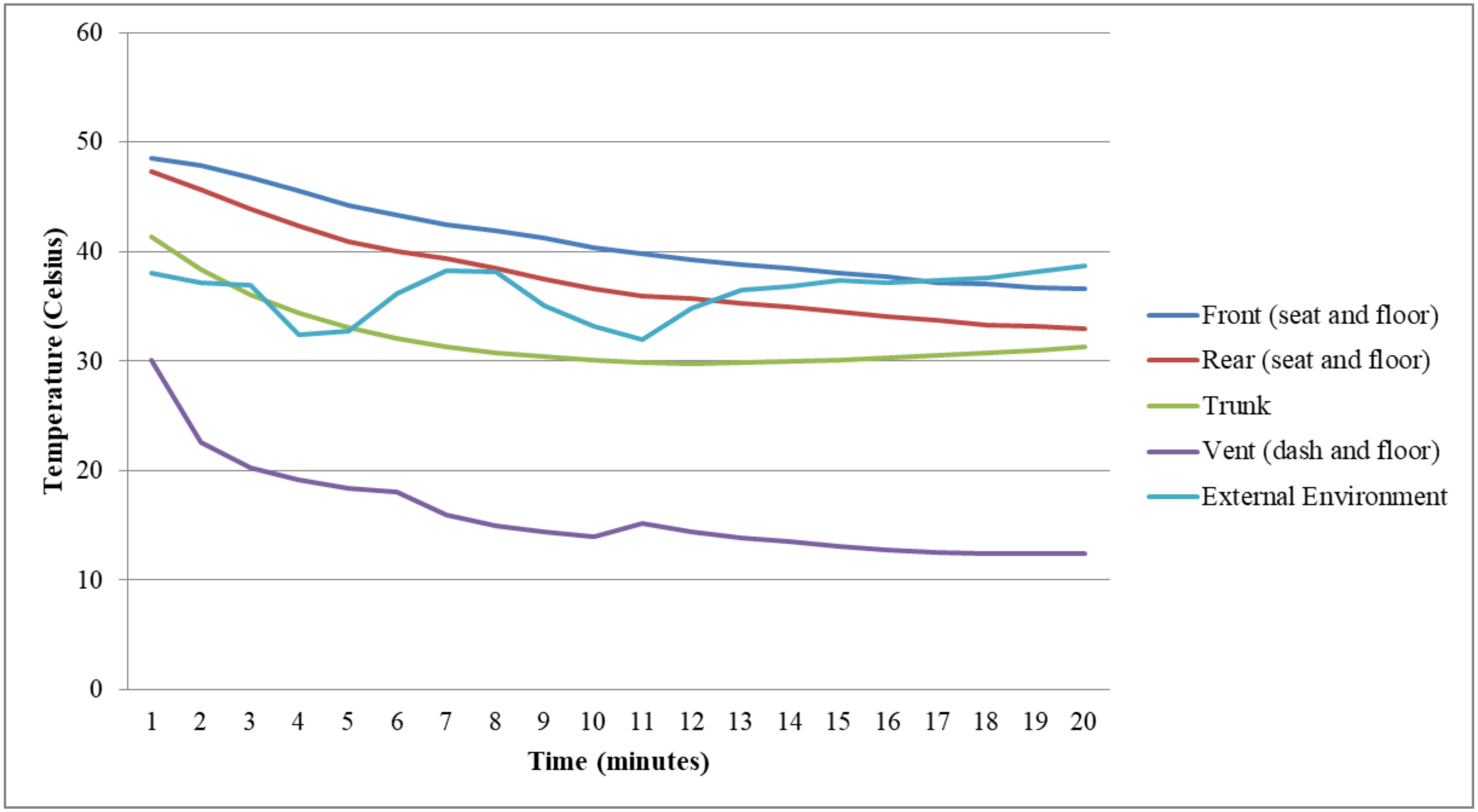

Figure 10. Simple means of vehicular and environmental temperatures with air conditioning in vehicle when driving from retail to residence when environmental temperatures exceeded 32.22 °C.

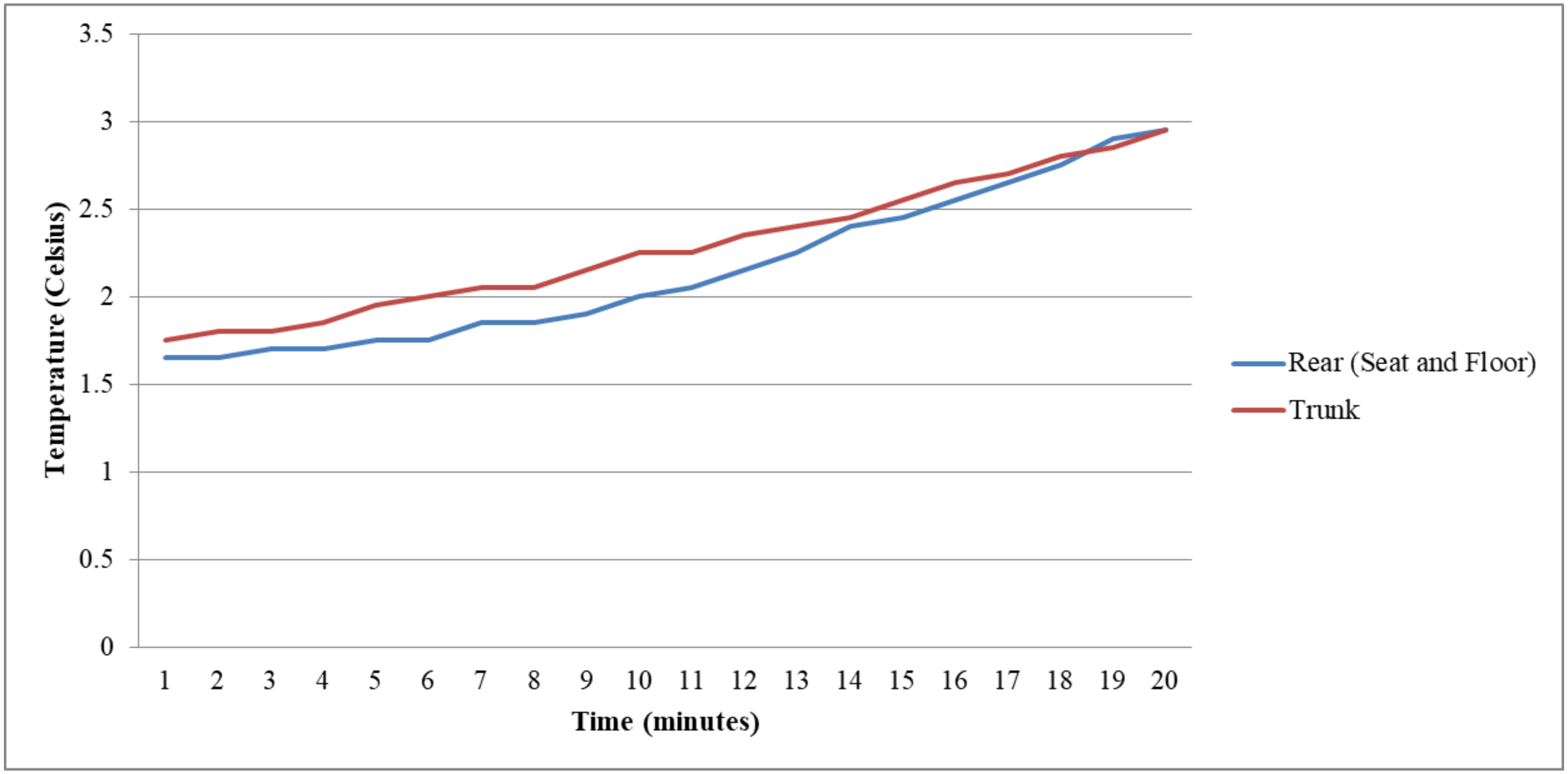

Figure 11. Simple means of internal temperature of over-wrap packaged ground beef with no temperature protection in vehicle with air conditioning during transport from retail to residence when environmental temperatures exceeded 32.22 °C.

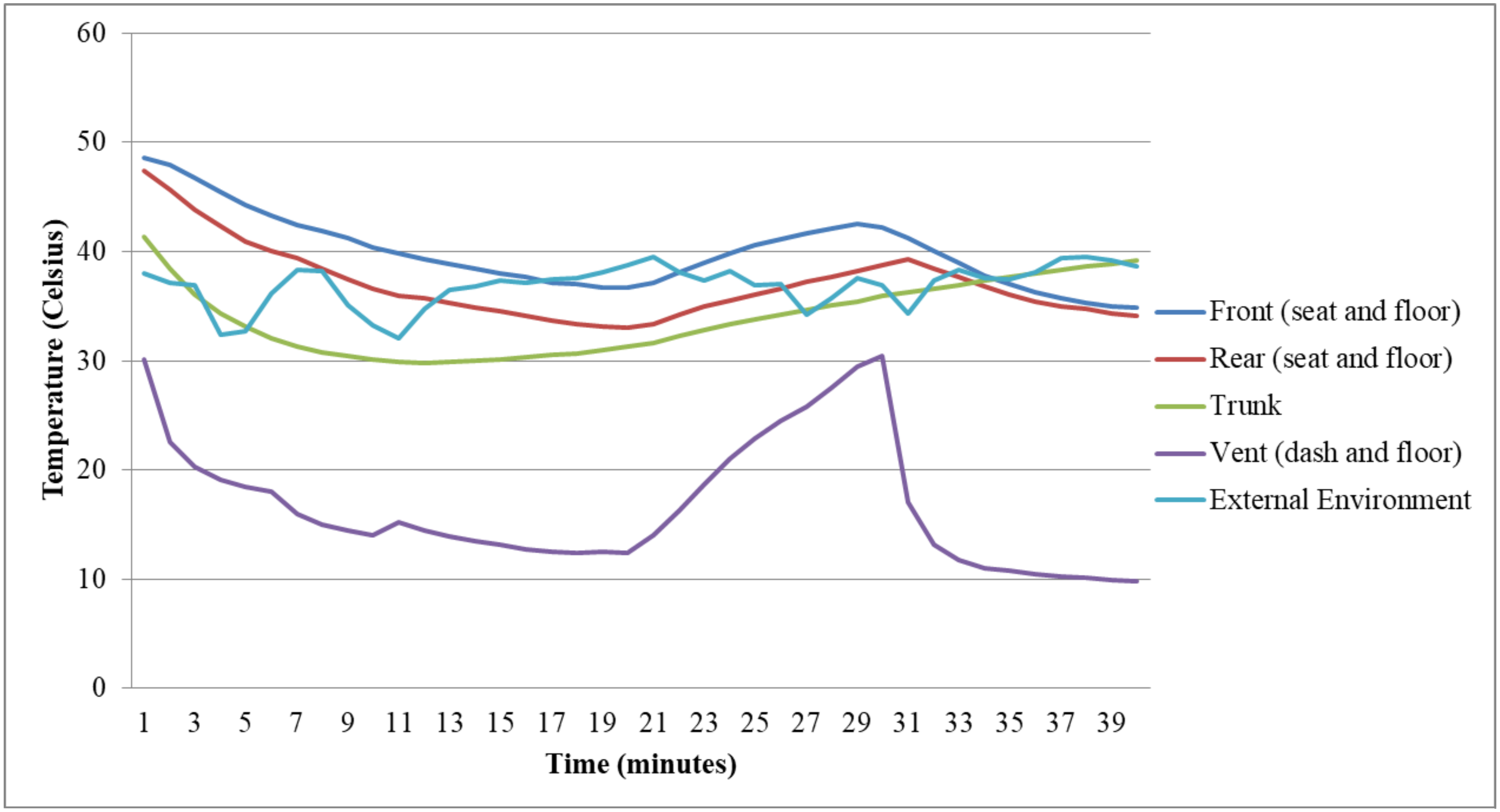

Figure 12. Simple means of vehicular and environmental temperatures during an errand simulation (20 minutes with air conditioning- 10 minutes vehicle turned off- 10 minutes with air conditioning) when driving from retail to residence when environmental temperatures exceeded 32.22 °C.

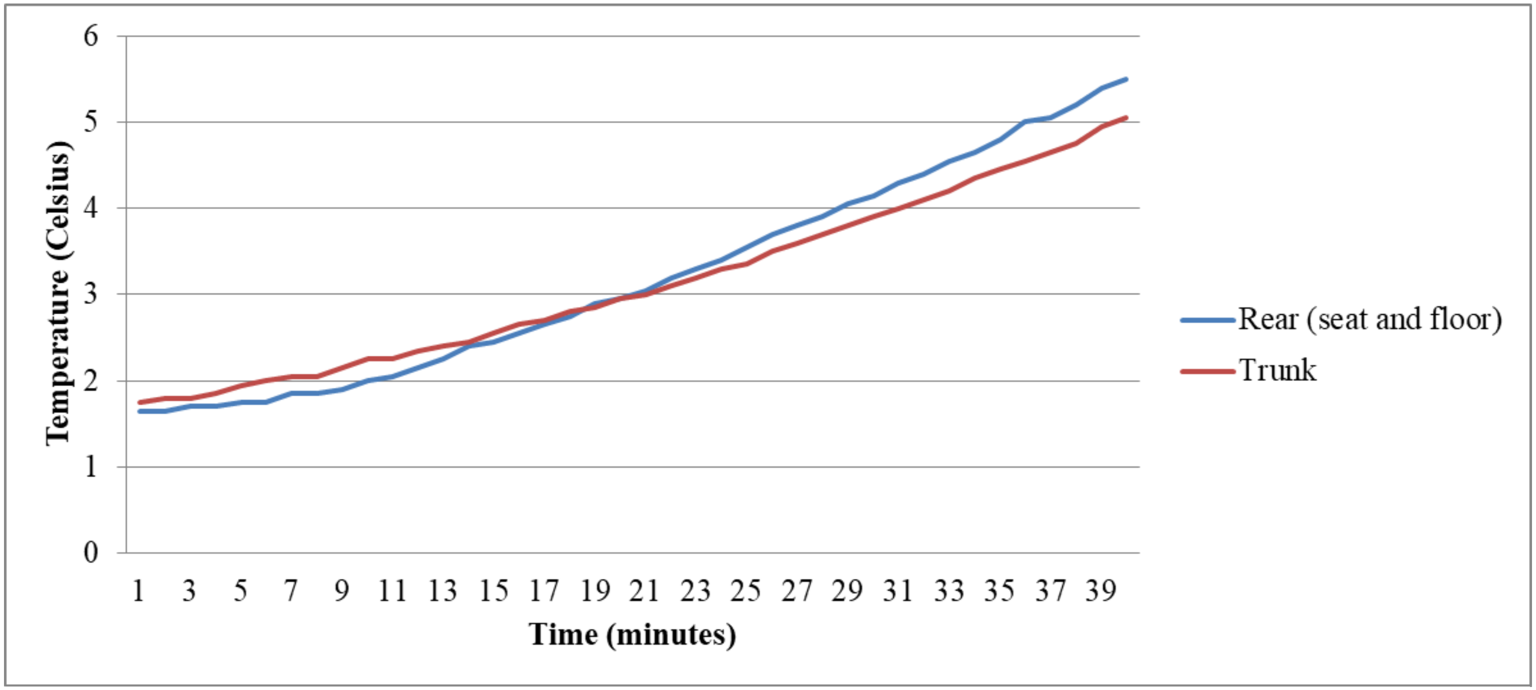

Figure 13. Simple means of internal temperature of over-wrap packaged ground beef with no temperature protection in vehicle during an errand simulation (20 minutes with air conditioning- 10 minutes vehicle turned off- 10 minutes with air conditioning) when driving from retail to residence when environmental temperatures exceeded 32.22 °C.

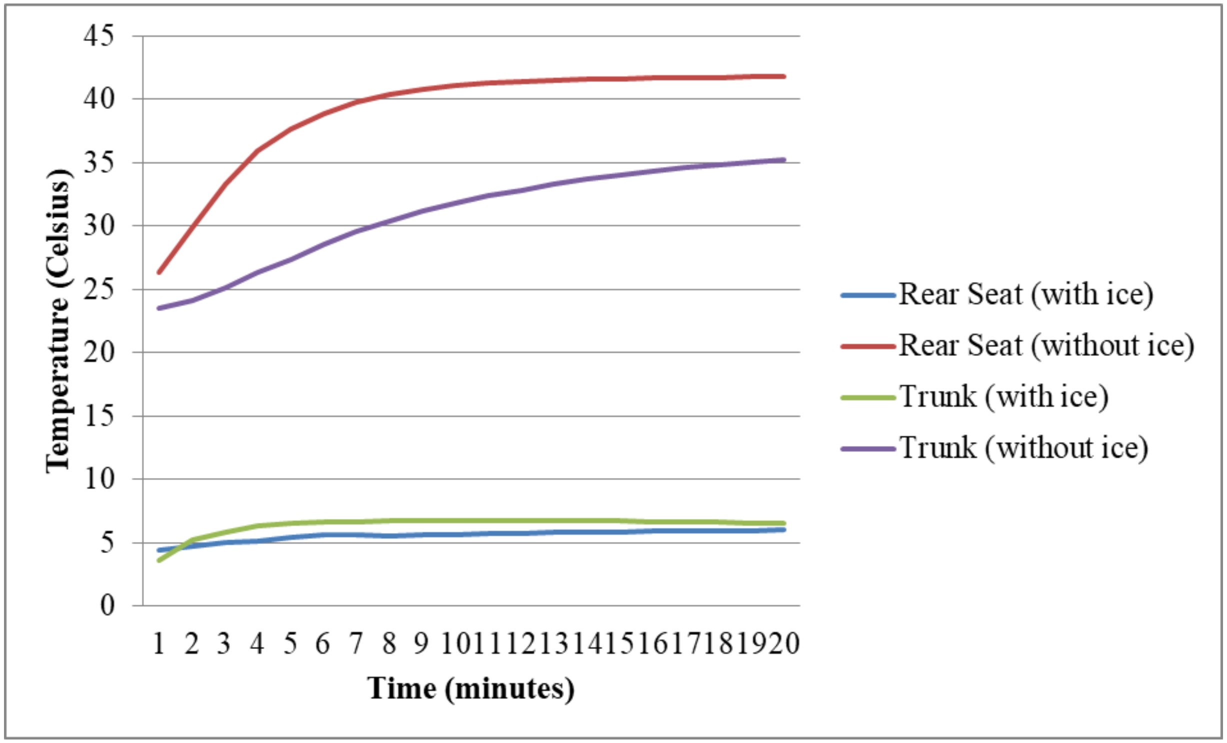

Figure 14. Simple means of cooler bag internal temperature pre-chilled with ice or not pre-chilled without ice in vehicle without air conditioning when driving from retail to residence when environmental temperatures exceeded 32.22 °C.

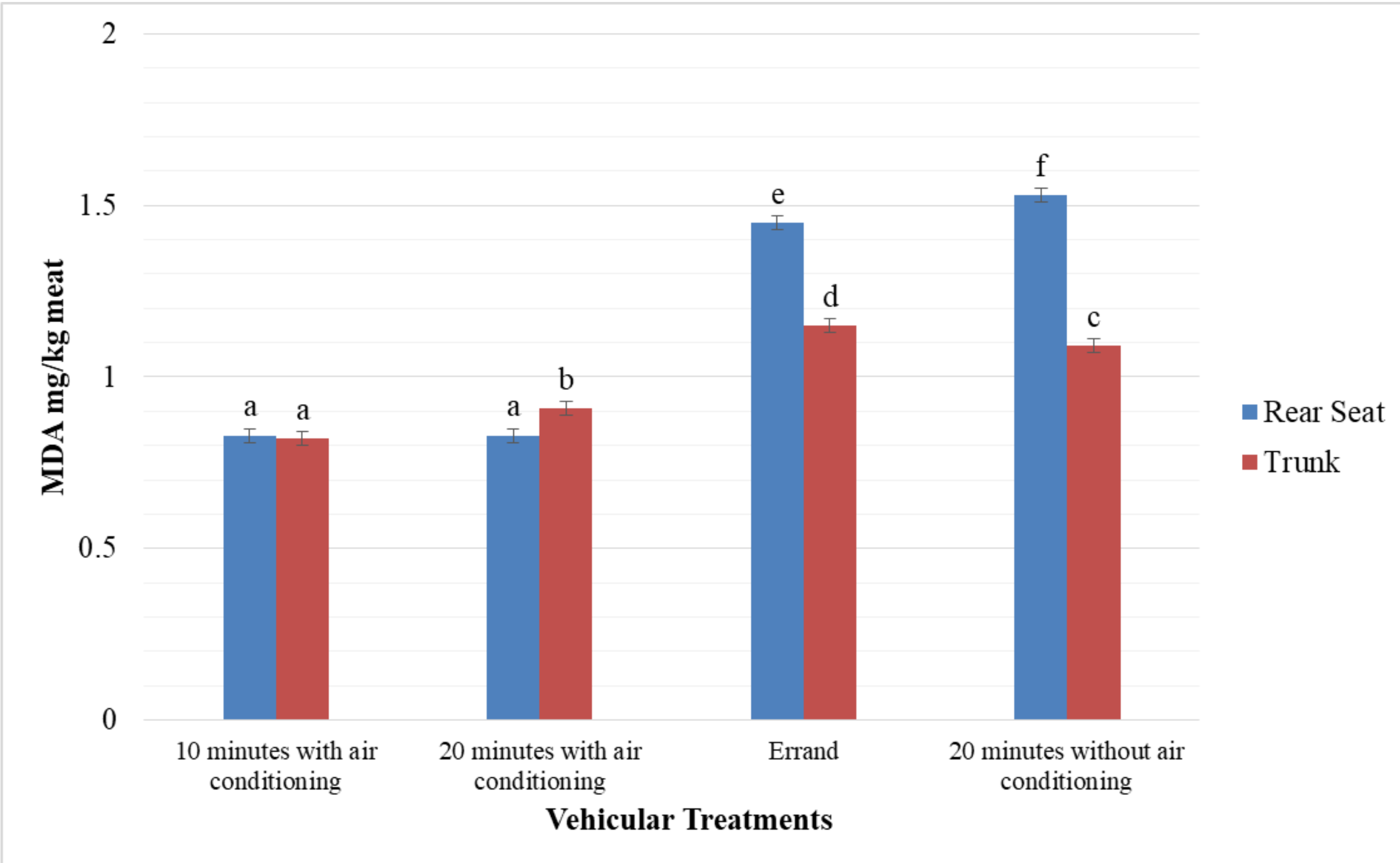

Figure 15. Least squares means of treatment x location interaction (P<0.0001) in vehicle on TBARS (mg MDA/kg meat) in transported over-wrapped packaged ground beef without temperature protection.

Table 23. Simple means of time-to-failure[1] for over-wrap packaged ground beef during vehicular transport from retail to residence without temperature protection.

Trait	Time-to-Failure, minutes	
Location (Vehicular Placement)	Rear Seat	Trunk
Time (minutes)		
Air Conditioning On[3]		
10	-	-
20	-	-
Errand[4]		
20-10-10	33	35
Air Conditioning Off		
20	13	-

[1]: Time-to-Failure= time until an internal temperature of 4.4444 °C is exceeded.
[2]: Medium fan speed from both dash and floor vents with at 16.02±5.63 °C.
[3]: Errand Simulation: 20 minutes with air conditioning on; 10 minutes vehicle off; 10 minutes with air conditioning on.

Table 24. Simple means of surface temperature for over-wrap packaged ground beef during vehicular transport from retail to residence without temperature protection.

Trait	Surface Temperature, °C	
Location (Vehicular Placement)	Rear Seat	Trunk
Time (minutes)		
Air Conditioning On[1]		
10	11.36	10.16
20	14.68	14.15
Errand[2]		
20-10-10	16.35	16.97
Air Conditioning Off		
20	17.51	15.04

[1]: Medium fan speed from both dash and floor vents with at 16.02±5.63 °C.
[2]: Errand Simulation: 20 minutes with air conditioning on; 10 minutes vehicle off; 10 minutes with air conditioning on.

Table 25. Least squares means for colorimetric values and SEM for packaged ground beef during vehicular transport from retail to residence without temperature protection.

Trait	L*			a*			b*		
	Treatment	Location	Interaction	Treatment	Location	Interaction	Treatment	Location	Interaction
Model Significance	P=0.0770	P=0.6071	P=0.2126	P=0.4442	P=0.2704	P=0.3721	P=0.3473	P=0.1831	P=0.2687
Time (minutes)									
Air Conditioning On[1]									
10	45.20±0.42	-	-	21.41±0.36	-	-	19.54±0.37	-	-
20	43.76±0.42	-	-	21.02±0.36	-	-	19.09±0.37	-	-
Errand[2]									
20-10-10	44.85±0.42	-	-	20.81±0.36	-	-	19.66±0.37	-	-
Air Conditioning Off									
20	43.62±0.42	-	-	20.54±0.36	-	-	18.73±0.37	-	-
Location (vehicle)									
Placement									
Rear Seat	-	44.24±0.30	-	-	20.79±0.26	-	-	18.98±0.26	-
Trunk	-	44.47±0.30	-	-	21.16±0.26	-	-	19.53±0.26	-

[1]: Medium fan speed from both dash and floor vents with at 16.02 ± 5.63 °C.

[2]: Errand Simulation: 20 minutes with air conditioning on; 10 minutes vehicle off; 10 minutes with air conditioning on.

Values lacking common superscript differ (P<0.05).

Table 26. Least squares means of discoloration and chroma values and SEM for packaged ground beef during vehicular transport from retail to residence without temperature protection.

Trait	Discoloration[1]			Chroma[2]		
Model Significance	Treatment P=0.0561	Location P=0.4579	Interaction P=0.0745	Treatment P=0.4601	Location P=0.2111	Interaction P=0.3560
Time (minutes)						
Air Conditioning On[3]						
10	1.09±0.01	-	-	40.96±0.72	-	-
20	1.10±0.01	-	-	40.11±0.72	-	-
					-	-
Errand[4]						
20-10-10	1.05±0.01	-	-	40.47±0.72	-	-
Air Conditioning Off						
20	1.09±0.01	-	-	39.28±0.72	-	-
Location (Vehicle)						
Placement						
Rear Seat	-	1.09±0.01	-	-	39.71±0.51	-
Trunk	-	1.08±0.01	-	-	40.70±0.51	-

[1]: Value = (a*/b*); higher ratios indicate more redness and less discoloration.
[2]: Value = (a*2+b*2)(0.5); higher values indicate more saturation of principle hue.
[3]: Medium fan speed from both dash and floor vents with at 16.02±5.63 °C.
[4]: Errand Simulation: 20 minutes with air conditioning on; 10 minutes vehicle off; 10 minutes with air conditioning on.
Values lacking common superscript differ (P<0.05).

Table 27. Simple means for subjective color and discoloration for over-wrap packaged ground beef transported from retail to residence without temperature protection.

Trait[1]	Initial Color	Post-treatment Color	Initial Discoloration	Post-treatment Discoloration
Time (minutes)				
Air Conditioning On[2]				
10	1.00	1.00	2.00	2.00
20	1.00	2.00	2.00	2.00
Errand[3]				
20-10-10	1.00	2.00	2.00	2.00
Air Conditioning Off				
20	1.00	2.00	2.00	3.00

[1]: An eight-point scale was used for the evaluations of color and discoloration (1= very light red, very bright red to 8= dark red, tan).
[2]: Medium fan speed from both dash and floor vents with at 16.02±5.63 °C.
[3]: Errand Simulation: 20 minutes with air conditioning on; 10 minutes vehicle off; 10 minutes with air conditioning on.

Table 28. Simple means for subjective off-odor and purge for over-wrap packaged ground beef transported from retail to residence without temperature protection.

Trait	Off-Odor[1]	Initial Purge, %	Post-treatment Purge, %
Treatment and Time (minutes)			
Air Conditioning On[2]			
10	1.00	0.75	1.37
20	1.50	0.50	0.87
Errand[3]			
20-10-10	1.50	0.62	1.12
Air Conditioning Off			
20	1.50	0.62	1.25

[1]: A five-point scale was used for the evaluation of off-odor (1= No off-odor to 5= Extreme off-odor).
[2]: Medium fan speed from both dash and floor vents with at 16.02±5.63 °C.
[3]: Errand Simulation: 20 minutes with air conditioning on; 10 minutes vehicle off; 10 minutes with air conditioning on.

Table 29. Least squares means of cook loss and Allo-Kramer shear force values and SEM for packaged ground beef during vehicular transport from retail to residence without temperature protection.

Trait	Cook loss, %			Allo-Kramer Shear, kg		
	Treatment	Location	Interaction	Treatment	Location	Interaction
Model Significance	P=0.0011	P=0.2113	P=0.0584	P=0.0007	P=0.1041	P=0.2056
Time (minutes)						
Air Conditioning On[1]						
10	28.75±0.49^{a}	-	-	12.04±0.60^{a}	-	-
20	29.06±0.49^{a}	-	-	12.29±0.60^{a}	-	-
					-	-
Errand[2]						
20-10-10	28.72±0.49^{a}	-	-	12.38±0.60^{a}	-	-
Air Conditioning Off						
20	31.52±0.49^{b}	-	-	15.66±0.60^{b}	-	-
Location (Vehicle)						
Placement						
Rear Seat	-	29.83±0.35	-	-	12.58±0.42	-
Trunk	-	29.19±0.35	-	-	13.61±0.42	-

[1]: Medium fan speed from both dash and floor vents with at 16.02 ± 5.63 °C.

[2]: Errand Simulation: 20 minutes with air conditioning on; 10 minutes vehicle off; 10 minutes with air conditioning on.

Values lacking common superscript differ ($P<0.05$).

Table 30. Least squares means for initial juiciness, sustained juiciness, and cohesiveness and SEM for packaged ground beef during vehicular transport from retail to residence without temperature protection.

Trait[1]	Initial Juiciness			Sustained Juiciness			Cohesiveness		
	Treatment	Location	Interaction	Treatment	Location	Interaction	Treatment	Location	Interaction
Model Significance	P=0.3282	P=0.0120	P=0.3056	P=0.3550	P=0.0087	P=0.8695	P=0.8098	P=0.6000	P=0.8638
Time (minutes)									
Air Conditioning On[2]									
10	5.25±0.22	-	-	5.00±0.20	-	-	4.90±0.20	-	-
20	5.03±0.22	-	-	4.84±0.20	-	-	4.93±0.20	-	-
Errand[3]									
20-10-10	5.18±0.22	-	-	4.93±0.20	-	-	5.12±0.20	-	-
Air Conditioning Off									
20	4.71±0.22	-	-	4.53±0.20	-	-	5.12±0.20	-	-
Location (vehicle)									
Placement									
Rear Seat	-	4.76±0.15[a]	-	-	4.56±0.14[a]	-	-	4.96±0.14	-
Trunk	-	5.32±0.15[b]	-	-	5.09±0.14[b]	-	-	5.07±0.14	-

[1]: An eight-point scale was used for the evaluations of initial and sustained juiciness and cohesiveness (1= extremely dry, extremely crumbly to 8= extremely juicy, extremely cohesive).
[2]: Medium fan speed from both dash and floor vents with at 16.02±5.63 °C.
[3]: Errand Simulation: 20 minutes with air conditioning on; 10 minutes vehicle off; 10 minutes with air conditioning on.
Values lacking common superscript differ (P<0.05).

Table 31. Least squares means for beef flavor intensity and off-flavor intensity values and SEM for packaged ground beef during vehicular transport from retail to residence without temperature protection.

Trait[1]	Beef Flavor Intensity			Off-flavor Intensity		
	Treatment	Location	Interaction	Treatment	Location	Interaction
Model Significance	P=0.8802	P=0.2496	P=0.6690	P=0.1249	P=0.1762	P=0.1415
Time (minutes)						
Air Conditioning On[2]						
10	4.78±0.16	-	-	1.00±0.08	-	-
20	4.68±0.16	-	-	1.25±0.08	-	-
					-	-
Errand[3]						
20-10-10	4.87±0.16	-	-	1.21±0.08	-	-
Air Conditioning Off						
20	4.78±0.16	-	-	1.18±0.08	-	-
Location (Vehicle)						
Placement						
Rear Seat	-	4.68±0.11	-	-	1.21±0.06	-
Trunk	-	4.87±0.11	-	-	1.11±0.06	-

[1]: An eight-point scale was used for the evaluations of beef flavor intensity and off-flavor intensity (1= extremely bland, no off flavor to 8= extremely intense beef, and extreme off flavor).
[2]: Medium fan speed from both dash and floor vents with at 16.02±5.63 °C.
[3]: Errand Simulation: 20 minutes with air conditioning on; 10 minutes vehicle off; 10 minutes with air conditioning on.
Values lacking common superscript differ (P<0.05).

Table 32. Least squares means of L* values and SEM for over-wrap packaged ground beef during vehicular transport from retail to residence without temperature protection.

Trait	L*			
Model Significance	Day P<0.0001	Treatment P=0.5949	Location P=0.0480	Interaction P≥0.4579
Day				
1	44.86±0.26[abc]	-	-	-
2	44.57±0.26[a]	-	-	-
3	44.80±0.26[abc]	-	-	-
4	45.49±0.26[cd]	-	-	-
5	44.71±0.26[ab]	-	-	-
6	45.35±0.26[bcd]	-	-	-
7	46.03±0.26[de]	-	-	-
8	47.08±0.26[f]	-	-	-
9	46.77±0.26[ef]	-	-	-
10	46.96±0.26[f]	-	-	-
Time (minutes)				
Air Conditioning On[1]				
20	-	45.62±0.12	-	-
Air Conditioning Off				
20	-	45.71±0.12	-	-
Location (Vehicle)				
Placement				
Rear Seat	-	-	45.84±0.12[a]	-
Trunk	-	-	45.49±0.12[b]	-

[1]: Medium fan speed from both dash and floor vents with at 16.02±5.63 °C.
Values lacking common superscript differ (P<0.05).

Table 33. Least squares means of a* values and SEM for over-wrap packaged ground beef during vehicular transport from retail to residence without temperature protection.

Trait	a*			
Model Significance	Day P<0.0001	Treatment P=0.0404	Location P=0.0614	Interaction P≥0.2396
Day				
1	20.67±0.16[a]	-	-	-
2	17.60±0.16[b]	-	-	-
3	15.24±0.16[c]	-	-	-
4	13.22±0.16[d]	-	-	-
5	11.61±0.16[e]	-	-	-
6	10.29±0.16[f]	-	-	-
7	9.11±0.16[g]	-	-	-
8	8.24±0.16[h]	-	-	-
9	7.16±0.16[i]	-	-	-
10	6.61±0.16[j]	-	-	-
Time (minutes)				
Air Conditioning On[1]				
20	-	12.08±0.07[a]	-	-
Air Conditioning Off				
20	-	11.86±0.07[b]	-	-
Location (Vehicle)				
Placement				
Rear Seat	-	-	11.87±0.07	-
Trunk	-	-	12.07±0.07	-

[1]: Medium fan speed from both dash and floor vents with at 16.02±5.63 °C.
Values lacking common superscript differ (P<0.05).

Table 34. Least squares means of b* values and SEM for over-wrap packaged ground beef during vehicular transport from retail to residence without temperature protection.

Trait	b*			
Model Significance	Day P<0.0001	Treatment P=0.0009	Location P=0.0091	Interaction P≥0.3229
Day				
1	19.08±0.19[a]	-	-	-
2	18.23±0.19[b]	-	-	-
3	17.22±0.19[c]	-	-	-
4	16.85±0.19[cd]	-	-	-
5	16.28±0.19[d]	-	-	-
6	16.20±0.19[d]	-	-	-
7	16.01±0.19[d]	-	-	-
8	16.14±0.19[d]	-	-	-
9	16.18±0.19[d]	-	-	-
10	16.40±0.19[d]	-	-	-
Time (minutes)				
Air Conditioning On[1]				
20	-	17.08±0.09[a]	-	-
Air Conditioning Off				
20	-	16.64±0.09[b]	-	-
Location (Vehicle)				
Placement				
Rear Seat	-	-	16.69±0.09[b]	-
Trunk	-	-	17.03±0.09[a]	-

[1]: Medium fan speed from both dash and floor vents with at 16.02±5.63 °C.
Values lacking common superscript differ (P<0.05).

Table 35. Least squares means of discoloration values and SEM for over-wrap packaged ground beef during vehicular transport from retail to residence without temperature protection.

Trait	Discoloration[1]			
Model Significance	Day P<0.0001	Treatment P=0.0216	Location P=0.6529	Interaction P≥0.1559
Day				
1	1.08±0.005[a]	-	-	-
2	0.96±0.005[b]	-	-	-
3	0.88±0.005[c]	-	-	-
4	0.78±0.005[d]	-	-	-
5	0.71±0.005[e]	-	-	-
6	0.63±0.005[f]	-	-	-
7	0.56±0.005[g]	-	-	-
8	0.51±0.005[h]	-	-	-
9	0.44±0.005[i]	-	-	-
10	0.40±0.005[j]	-	-	-
Time (minutes)				
Air Conditioning On[2]				
20	-	0.69±0.003[b]	-	-
Air Conditioning Off				
20	-	0.70±0.003[a]	-	-
Location (Vehicle)				
Placement				
Rear Seat	-	-	0.70±0.003	-
Trunk	-	-	0.69±0.003	-

[1]: Value = (a*/b*); higher ratios indicate more redness and less discoloration.
[2]: Medium fan speed from both dash and floor vents with at 16.02±5.63 °C.
Values lacking common superscript differ (P<0.05).

Table 36. Simple means of subjective discoloration values and SEM for over-wrap packaged ground beef during vehicular transport from retail to residence without temperature protection.

Trait	Subjective Discoloration[1]	
Treatment and Time (minutes)	Air Conditioning On[2] (20)	Air Conditioning Off (20)
Day		
1	2.0	3.0
2	3.0	3.0
3	3.0	3.0
4	3.5	4.0
5	5.0	5.0
6	6.0	6.0
7	6.0	6.0
8	7.0	7.0
9	8.0	8.0
10	8.0	8.0

[1]: An eight-point scale was used for the evaluation of discoloration (1= very bright red to 8= tan).
[2]: Medium fan speed from both dash and floor vents with at 16.02±5.63 °C.
Values lacking common superscript differ ($P<0.05$).

Table 37. Least squares means of chroma values and SEM for over-wrap packaged ground beef during vehicular transport from retail to residence without temperature protection.

Trait	Chroma[1]			
Model Significance	Day P<0.0001	Treatment P=0.0039	Location P=0.0169	Interaction P≥0.4293
Day				
1	39.76±0.33[a]	-	-	-
2	35.83±0.33[b]	-	-	-
3	32.46±0.33[c]	-	-	-
4	30.07±0.33[d]	-	-	-
5	27.89±0.33[e]	-	-	-
6	26.49±0.33[f]	-	-	-
7	25.11±0.33[g]	-	-	-
8	24.39±0.33[g]	-	-	-
9	23.34±0.33[h]	-	-	-
10	23.01±0.33[h]	-	-	-
Time (minutes)				
Air Conditioning On[2]				
20	-	29.16±0.15[a]	-	-
Air Conditioning Off				
20	-	28.51±0.15[b]	-	-
Location (vehicle)				
Placement				
Rear Seat	-	-	28.57±0.15[b]	-
Trunk	-	-	29.10±0.15[a]	-

[1]: Value = (a*2+b*2)(0.5); higher values indicate more saturation of principle hue.
[2]: Medium fan speed from both dash and floor vents with at 16.02±5.63 °C.
Values lacking common superscript differ (P<0.05).

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CHAPTER VI: Summary and Future Research

Summary

Unlike the controlled and highly regulated systematic steps in the production and handling of the fresh red meat products prior to purchase, a consumer's handling behavior cannot be regulated by an outside authority after the product has reached a consumer's hands. Improper consumer handling behaviors ultimately lead to food waste and reduced sustainability both domestically and globally. Annual food waste has increased over 50 % since the 1970's. In the United States, 3,000 pounds of food is wasted every second with 12 % of food waste being meat equating to 21,600 pounds of meat per hour (Morgan, 2012). Given the volatility of meat due to reactions with the extrinsic environment, a greater understanding of consumer handling behavior in retail locations and during transport to residence is needed to provide educators, industry, and ultimately consumers with greater knowledge of proper handling behaviors and consequent accountability. This research first investigated consumer behaviors regarding fresh beef product handling, specifically during the period of transport from retail to residence, utilizing survey methodology. Next, the rate at which fresh beef products increase in temperature upon placement in cart or basket at retail locations, and the subsequent effects on palatability and consumer appeal as well as the implications of improper consumer handling behaviors during transport from retail to residence on temperature and meat quality were evaluated. Ultimately, this research was designed with the consumer in mind and the goal was to mimic the way a consumer would handle fresh beef products during vehicular transport from retail to residence.

Consumer questionnaire studies related to consumer product handling behaviors are scarce, and university extension programs have narrowly focused on in-home handling behaviors due to the lack of consumer-based research on actual handling behaviors. A 13-item questionnaire utilizing the Qualtrics survey platform was randomly distributed across the United States through electronic media. A 43-day response period generated 1,554 responses with 1,484 completed questionnaires yielding a 95.5 % completion rate. Our research determined that regardless of the increased consumer awareness to food manufacturing from farm to plate, the study revealed there is still 91.8 % chance a food could be transported without temperature protection. Furthermore, over a 12 year span, the use of temperature protective items such as cooler bags has increased only 1.2 %. Additionally, the present study found consumers will continue shopping in a retail food location up to an hour with a fresh beef product left sitting in the cart or basket. Upon checkout, most consumers will place a fresh beef product in the rear seat and floor or trunk or cargo space of the vehicle. Furthermore, 25.8 % of consumers will run additional errands with fresh beef products left sitting in the vehicle for greater than 60 minutes. An insulated bag is most commonly used for temperature abuse protection. The questionnaire revealed age, sex, ethnicity, and attained education directly influenced fresh beef handling behavior in a retail food location and during vehicular transport to residence.

The retail display case symbolizes the beginning of the consumer cold chain. The initial interaction between the consumer and the fresh beef product within the retail case and food retailer drives numerous factors including perceived palatability and ultimate purchase. Temperature is one of the most impactful characteristics related to the retail display case. Our research determined fresh meat product temperature abuse can occur in the cart at a retail food location prior to check-out. Once removed from the retail display case and placed in cart, the average time needed to exceed the safe internal temperature of 4.4 °C in over-wrap packaged ground beef is approximately 49 minutes given the retail environmental temperature of 21.2 °C. Time in cart directly influenced color acceptability and oxidative rancidity.

Research has established that consumer behaviors related to temperature abuse are detrimental to palatability; nonetheless, the emphasis has directly concentrated on in-residence storage, thawing, and cooking methods, not temperature abuse during transport. Our study found temperature abuse can occur during vehicular transport from retail to residence. Internal vehicular temperature can exceed environmental temperature during meat transport from retail to residence. Given the absence of air conditioning during transport, the trunk as opposed to the rear seat of the vehicle maintains a lower temperature which is more suitable to mitigating temperature abuse given direct transport to residence. When transported without air conditioning and an environmental temperature exceeding 32.2, temperature dependent foods such as fresh red meat products placed on the rear seat of the vehicle for transport will exceed the safe minimum internal temperature of 4.4 °C in approximately 13 minutes. Furthermore, running an errand with a fresh beef product left in the vehicle will ultimately induce temperature abuse which occurs when the vehicle is re-started. Regardless of placement location within the vehicle, over-wrap packaged ground beef transported from retail to residence in 20 minutes or less with exposure to air conditioning did not exceed an internal temperature of 4.4 °C. Importantly, this study showed internal meat temperature will increase regardless of transport conditions. Nonetheless, the use of air conditioning reduced the rate of temperature internal temperature increase. The use of ice in a cooler bag is a must since the temperature will increase to 38.5 °C inside the bag without ice present as opposed to being maintained at less than 7.0 °C with ice inside given environmental temperatures exceed 32.2 °C. The palatability components of tenderness, juiciness, and flavor as well as color appeal are all impacted during transport from retail to residence since fresh beef products are most commonly left vulnerable by consumers in temperature abusive vehicular environments. Abusive vehicular conditions produced tough, dry, and oxidized ground beef. Additionally, color appeal was not immediately affected after transport, but differences were seen in long-term refrigerated storage.

The results from this research will be used to provide a greater understanding of consumer behavior to the meat industry enabling further focus and development of future technological improvements and marketing strategies for this specific consumer behavior. Thus, increased consumer awareness could ultimately reduce food waste and enhance sustainability in the United States.

Future Research

The current study was exploratory and thus, provided a foundation and data for future research. The first step in future research is to determine the effects of vehicular temperature abuse on spoilage microorganism proliferation and food safety. Research is also needed to determine the effects of transporting fresh beef products in a cooler with ice or without ice on temperature, color appeal, and palatability. This was not evaluated since the current research project mimicked consumer behaviors determined by the survey. Additionally, the impact of vehicular conditions on other meat products including fresh, processed, and even different species is needed to further enhance consumer awareness and knowledge.

The possibilities for research related to the consumer cold chain are boundless since current research is scarce. The ideas and directions of future research discussed herein represent only a minute portion of the existing opportunities. Without question, new research will be identified and pursued as consumers continue to interact with food and since the grocer is evolving from brick and mortar to direct delivery as well as the growth of farm-fresh markets.

APPENDICES

Appendix A. Safe Minimum Internal Temperatures

Illustration. Safe Minimum Internal Temperatures for Meat.	
Meat Product	Temperature and Rest Time
Intact: Beef, Pork, Veal, and Lamb	145 °F (62.8 °C) and allow to rest for at least 3 minutes.
Ground Products	160 °F (71.1 °C).
Un-cooked Ham	145 °F (62.8 °C) and allow to rest for at least 3 minutes.
Fully-cooked Ham	Reheat cooked hams packaged in USDA-inspected plants to 140 °F (60 °C) and all others to 165 °F (73.9 °C).
All Poultry	165 °F (73.9 °C)
Leftovers	165 °F (73.9 °C)
Modified from USDA-FSIS (2012): Safe Minimum Internal Temperature Chart.	

Appendix B. Meat Flavors and Aromas

Illustration. Meat Flavors and Aromas.	
Volatile Compound(s)	*Flavor(s) and Aroma(s)*
Pentanal	Pungent
Hexanal	Green, grassy, fatty
Heptanal	Green, fatty, oily
Nonanal	Soapy
Methional	Cooked potato
12-methyltridecanal	Beefy
Nona-2(E)-enal	Tallowy, fatty
Deca-2(E), 4(E)-dienal	Fatty, fried potato
Butanoic Acid	Rancid
Hexanoic Acid	Sweaty
Delta-nonalactone	Sweet, dairy, or waxy notes
Decan-2-one	Musty, fruity
3-Hydroxy-2-butanone	Buttery
2,3-Octanedione	Warmed over flavor, lipid oxidation
1-Octene-3-ol	Mushroom
2-Pentyl furan	Metallic, green, earthy, beany
2-methyl-3-[methylthio]furan	Meaty, sweet, sulfurous
4-hydroxy-5-methyl-3(2H)-furanone(HMF)	Meaty
Methylpyrazine, 2,5-(and 2,6-) dimethylpyrazine	Roasted, nutty
Pyrazines	Nutty, cracker-like, bell pepper
Amino Acids: glycine, alanine, lysine, cysteine, methionine, glutamine, succinic	Sweet
Organic Acids: lactic, inosinic, ortho-phosphoric, pyrrolidone carboxylic	Sweet
Sugars: glucose, fructose, ribose	Sweet
Amino Acids: aspartic acid, histidine, asparagines	Sour
Organic Acids: succinic, lactic, inosinic, ortho-phosphoric, pyrrolidone carboxylic	Sour
Hypoxyanthine, anserine, carnosine	Bitter
Amino Acids: arginine, leucine, tryptophan	Bitter
Monosodium glutamate, inosine and guanosine monophosphate	Savory, broth, beefy
Bis(2-methyl-3-furyl) disulfide	Roasted Meat
2-methyl-3-furanthiol	Roasted Meat
Modified from Brewer (2006) in reference to Rowe, 2002; Mottram 1998; Shahidi, 1998; Macleod, 1994; Maga, 1994; Spanier and Miller, 1993; Spanier et al., 1992; Macleod and Ames, 1986.	

Appendix C. USDA Quality Grade and Intramuscular Fat Percentage

Illustration. USDA Quality Grade and Intramuscular Fat Percentage (IMF%)		
Degrees of Marbling	*USDA Quality Grade (A)*	*IMF%*
Slight 00 - 40	Low Select	2.3 – 3.0
Slight 50 - 90	High Select	3.1 – 3.9
Small 00 - 90	Low Choice	4.0 – 5.7
Modest 00 - 90	Average Choice	5.8 – 7.6
Moderate 00 - 90	High Choice	7.7 – 9.7
Slightly Abundant 00 - 90	Low Prime	9.8 – 12.1
Moderately Abundant 00- 90	Average Prime	12.2 - Higher
Modified from Wilson et al. (1998).		

Appendix D. Palatability Preference Change Over Time

Illustration. Palatability Preference Change Over Time.				
Citation	Location and Sample Size	Tenderness (%)	Juiciness (%)	Flavor (%)
Miller et al. (1995)	TX; n = 452	50.0	40.0	10.0
Huffman et al. (1996)	TX; n = 75	51.0	39.0	10.0
Platter et al. (2003)	CO; n = 489	52.0	38.0	11.0
Corbin et al. (2015)	TX; n = 120	30.8	50.8	18.4

Appendix E. Electronic Questionnaire

Information Letter You are invited to voluntarily participate in a survey research study to investigate consumer behaviors regarding fresh red meat product handling. The study is being conducted by Dr. Christy Bratcher, Associate Professor in the Auburn University Department of Animal Sciences. A critical problem in the field of meat science is the lack of understanding of consumer handling practices during transport from retail to residence and the subsequent effect on desired palatability traits such as tenderness, juiciness, and flavor. Therefore, the purpose of this study is to investigate consumer behaviors regarding fresh beef product handling during the period of transport from retail to residence. At maximum, 3 minutes of your time will be needed to complete the survey. All data will remain anonymous and confidential since no identifiable information will be collected. HAVING READ THE INFORMATION PROVIDED, SELECTING ">>" IS YOUR CONSENT TO PARTICIPATE.

The Auburn University Institutional Review Board has approved this document for use from 7/11/16 to 7/10/17. Protocol 16-245.

Age Verification By selecting yes, I certify that I am 19 years of age or older.

- ❍ Yes (1)
- ❍ No (2)

If No Is Selected, Then Skip To End of Survey

Q1 What time of day do you most often go grocery shopping?

- ❍ Morning (5:00 a.m. to 11:59 a.m.) (1)
- ❍ Afternoon (Noon to 4:59 p.m.) (2)
- ❍ Evening (5:00 p.m. to 8:59 p.m.) (3)
- ❍ Night (9:00 p.m. to 4:59 a.m.) (4)

Q2 Once you have placed the fresh beef product in your cart or basket, usually how long before you checkout?

- ❍ 5 minutes or less (1)
- ❍ 6 - 10 minutes (2)
- ❍ 11 - 20 minutes (3)
- ❍ 21 - 30 minutes (4)
- ❍ 31 - 60 minutes (5)

Q3 How long does it usually take for you to drive from the grocery store to where you currently live?

- 10 minutes or less (1)
- 11 - 20 minutes (2)
- 21 - 30 minutes (3)
- 31 - 59 minutes (4)
- 60 - 120 minutes (5)

Q4 Where are you most likely to place a fresh beef product in your vehicle?

- Front (including seat and floor) (1)
- Rear (including seat and floor) (2)
- Trunk or Cargo Space (3)
- Bed of Pickup Truck (4)

Q5 How often do you run other errands with fresh beef left sitting in the vehicle?

- Always (1)
- Frequently (2)
- Occasionally (3)
- Never (4)

If Never Is Selected, Then Skip To How often do you use an insulated pro...

Q6 While completing other errands, usually how long is fresh beef left sitting in your vehicle?

- 5 minutes or less (1)
- 6 - 10 minutes (2)
- 11 - 20 minutes (3)
- 21 - 30 minutes (4)
- 31 - 60 minutes (5)
- Greater than 60 minutes (6)

Q7 How often do you use an insulated product (i.e. cooler/bag) to transport fresh beef products from the grocery store to where you currently live?

- Always (1)
- Frequently (2)
- Occasionally (3)
- Never (4)

If Never Is Selected, Then Skip To Select the answer that best repr...

Q8 What type of insulated product do you most often use to transport fresh beef products from the grocery store to where you currently live?
- Insulated Bag (1)
- Personal Size (14.8 quart) Cooler (2)
- Medium (40 quart) Cooler (3)
- Large (70 quart) Cooler (4)
- Extra Large (100 quart) Cooler (5)

Q9 Please select the name brand of the insulated product you most commonly use.
- Coleman (1)
- Yeti (2)
- Igloo (3)
- Other (4) ____________________

Q10 Select the answer that best represents your age.
- 19 - 24 (1)
- 25 - 34 (2)
- 35 - 44 (3)
- 45 - 54 (4)
- 55 - 64 (5)
- 65 or older (6)

Q11 Select the answer that best represents your sex.
- Male (1)
- Female (2)

Q12 Select the answer that best represents your ethnicity (or race).
- Caucasian (1)
- Hispanic or Latino (2)
- African American (3)
- Native American or American Indian (4)
- Asian or Pacific Islander (5)
- Other (6) ____________________

Q13 Select the answer that best represents the highest level of education that you have completed.

- ❍ Less than high school degree (1)
- ❍ High school degree or equivalent (2)
- ❍ Some college but no degree (3)
- ❍ Technical certificate (4)
- ❍ Associate degree (5)
- ❍ Bachelor Degree (6)
- ❍ Graduate Degree (7)

Appendix F: Sample Sensory Form

Name: Date: Time: Project:

Sample No.	Initial Juiciness	Sustained Juiciness	Cohesiveness	Beef Flavor Intensity	Off-flavor Intensity	Off-flavor descriptor

Juiciness	Cohesiveness	Beef Flavor Intensity	Off-flavor Intensity	Off-flavor Descriptor
8=Extremely Juicy	8=Extremely Cohesive	8=Extremely Intense	8=Extremely Intense	8=Metallic
7=Very Juicy	7=Very Cohesive	7=Very Intense	7=Very Intense Off-flavor	7=Salty
6=Moderately Juicy	6=Moderately Cohesive	6=Moderately Intense	6=Intense Off-flavor	6=Livery
5=Slightly Juicy	5=Slightly Cohesive	5=Slightly Intense	5=Moderate Off-flavor	5=Grassy
4=Slightly Dry	4=Slightly Crumbly	4=Slightly Bland	4=Modest Off-flavor	4=Bitter
3=Moderately Dry	3=Moderately Crumbly	3=Moderately Bland	3=Small Off-flavor	3=Bloody
2=Very Dry	2=Very Crumbly	2=Very Bland	2=Slight Off-flavor	2=Rancid
1=Extremely Dry	1=Extremely Crumbly	1=Extremely Bland	1=No Off-flavor	1=Other-Explain