THE USE OF TIME-LAPSE VIDEO SURVEILLANCE TO EVALUATE MEAT COLOR

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Abstract: This study has two objectives; the first objective was to assess the ability to utilize time-lapse video technology to color score the *longissimus lumborum* (LL) muscle. The second objective was to determine the point in retail display consumers expect a discount or stop purchasing USDA low-Choice strip steaks. 8 USDA Choice strip loins were aged for 14 and 28 d postmortem. The loins were cut into steaks and placed in retail display under time-lapse video surveillance. A 7-member trained panel evaluated the 14 d aged steaks both in-person and on video footage for visual color, surface discoloration, and overall acceptability using a hedonic scale. The GLIMMIX Procedure of SAS was used to determine the least-square means of the color score results on each day, while the CORR procedure determined the correlation between in-person and video color scores. The correlation coefficient was r^2= 0.99 between in-person and video color scoring for all parameters. Three videos were selected from the steaks aged 28 d and placed into a consumer survey which was distributed via email and social media. The survey was taken by 1,080 participants and consisted of two sections, a demographics section and a video section (three videos). Respondents were asked to determine at which point they would expect a discount or stop purchasing the products in the videos. The GLIMMIX Procedure of SAS was used to determine the least square means of the main effect (video). There was a significant difference ($P < 0.05$) between the responses to the three videos. However, on average the respondents stated they would expect a discount between 100-107 h of retail display and stop purchasing between 132-139 h of retail display. In conclusion, video color scoring could serve as a vital tool for researchers to determine the acceptability of beef products at every hour of retail display.

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CHAPTER I

INTRODUCTION

Consumer purchasing decisions for meat products can be affected by many factors such as religion, culture, beliefs, product price, and perceived quality (Font-i-Furnols and Guerrero, 2014). Consumers' perceptions of meat quality are influenced by appearance, which is one of the most important elements influencing purchasing decisions (Corlett, 2021). When beef is displayed in stores, it will oxidize and change from oxymyoglobin to metmyoglobin (Mancini and Hunt, 2005). Consumers favor a bright cherry red color (oxymyoglobin) and link it with freshness, while dark red or brown (metmyoglobin) colors are disliked (Mancini and Hunt, 2005). Studies have shown that consumers begin to discriminate against meat with 20% metmyoglobin formation (MacDougall, 1982).

The evaluation of meat color is crucial to research, product development and identifying potential industry problems (AMSA, 2012). It is important to utilize objective and subjective color measurement to obtain the full picture of the product (Warner, 2014). Typical methods to measure color are with a color spectrophotometer in conjunction with trained panelist color scoring (Tomasevic et al., 2021). Researchers must work to pinpoint consumers purchasing preferences; however, these preferences can change depending on the economy, the political climate of the world, and consumers

ever-changing beliefs (Reicks et al., 2011). It is especially crucial to determine their purchasing decisions in relation to discoloration to eliminate economic loss and food waste (Suman et al., 2014). The characteristic of cherry-red color is not a reliable predictor of safety, however, failing to achieve customer expectations for safe and healthy meat can result in financial losses and waste (Ramanathan et al., 2020). Although, we cannot predict safety by evaluating meat discoloration, many consumers link color with wholesomeness and freshness. Therefore, meat color research is very crucial to determining retail acceptability.

Continually improving technology is also crucial for the meat industry to continue to advance and thrive. Using video surveillance, we can color score multiple times per day as well as use the same products for both trained and consumer panel color scoring. This can help researchers get a better view of consumers purchasing decisions. As technology continues to improve, our ability to assess discoloration and consumer preferences also improve. The objective of this study was to compare the utilization of time-lapse video technology and traditional in-person color scoring of the *longissimus lumborum* (LL) muscle in retail display as well as analyze consumers purchasing decisions.

CHAPTER II

REVIEW OF LITERATURE

Meat Color

Myoglobin is the main protein that gives meat its color (Suman and Joseph, 2013). Meat color is determined by the presence of the ligand and the valence of iron (Mancini and Hunt, 2005). As a result, the color of meat is principally determined by four chemical types of myoglobin: deoxymyoglobin, oxymyoglobin, metmyoglobin, and carboxymyoglobin (Suman and Joseph, 2013). Deoxymyoglobin is purple in color and occurs when no ligand is present, this is typically found in vacuum package products and is not typically accepted by consumers (Djenane and Roncalés, 2018). Oxymyoglobin is characterized as a bright cherry-red color and occurs when the myoglobin is oxygenated (Mancini and Hunt, 2005). This oxygenation is also known as bloom (Suman et al., 2014). Carboxymyoglobin also has a bright cherry-red color and occurs when meat is exposed to carbon monoxide usually in modified atmosphere packaging (Grebitus et al., 2013). Deoxymyoglobin, oxymyoglobin, and carboxymyoglobin all have heme iron in the ferrous state (Suman and Joseph, 2013). However, metmyoglobin is brown in color and occurs when the myoglobin is oxygenated, a water molecule is bound, and the heme iron is in the ferric state (MacDougall, 1982). Metmyoglobin typically occurs when meat

has been exposed to oxygen for long periods of time. This state of myoglobin is characterized as discoloration and is seen as unwholesome by many consumers (Mancini and Hunt, 2005; Feuz et al., 2020). Discolored cuts are often sold at a discount due to them being difficult to market (Suman et al., 2014). Discounting discolored products can lead to economic loss, but can also reduce economic loss by not discarding products once they discolor (Smith et al., 2000).

Postmortem Aging

Postmortem aging of beef products is used across the meat industry, with the two most common methods being dry aging and wet aging (Smith et al., 2008; Park et al., 2015; Ha et al., 2019). Wet aging is the method most predominantly used in the beef industry (Smith et al., 2008; Ha et al., 2019). Wet aging refers to a product held at refrigerated temperatures in a sealed barrier package such as a vacuum package (Smith et al., 2008). Most beef products sold at retail have been wet aged in a vacuum package bag to improve palatability and shelf life (Suman et al., 2014; Ramanathan et al., 2020). This aging period is typically 7-21 d postmortem (Suman et al., 2014), but can range from 1-358 d postmortem (Guelker et al., 2013). Age related changes in biological mechanisms, such as those controlling myoglobin redox chemistry and oxygen scavenging enzymes (mitochondria), can have an impact on color stability once the product enters retail display (Suman et al., 2014). Suman et al. (2014) found that as enzymes become less active with postmortem aging, which causes a quicker bloom as postmortem age increases. However, as postmortem age increases, the color stability typically declines (Suman et al., 2014). Extended aging periods can affect the product's discoloration rate (Mitacek et al., 2019; Ramanathan et al., 2020).

Color Measurement

The evaluation of color is crucial to research, product development, and identifying potential industry problems (AMSA, 2012). It is important to utilize objective and subjective color measurements to obtain the full picture of the product. Both instrumental color measurement and visual assessments are useful tools for meat color evaluation (GoÑI et al., 2008). The typical way to measure color is with a color spectrophotometer in conjunction with human color scoring (AMSA, 2012).

Using a spectrophotometer is objective while color scoring is typically more subjective (Warner, 2014). However, trained panelist color scoring should be more objective than consumer panelist color scoring (AMSA, 2012; Tomasevic et al., 2021). This is because every trained panelist must go through training before they participate in research studies, whereas consumers typically do not go through any training before participating (AMSA, 2012). However, trained panelists may still be subjective due to the way they see color, personal opinions, and previous panel experience (Carpenter et al., 2001). Nonetheless, trained panelists are more adept at using the hedonic scales than untrained panelists (Mancini and Hunt, 2005). GoÑI et al. (2008) discovered a comparable association between visual color evaluation and L^* and a^* values using various color reference standards and measuring tools.

United States 2020 Census

Data from the United States Census Bureau (2020) states that the estimated population of the United States as of July 1, 2021, is 331,893,745 with 50.5% being female. The ethnic background of the United States in 2020 was: 75.8% Caucasian,

13.6% African American, 6.4% Asian or Pacific Islander, and 1.3% American Indian or Alaskan Native. Of the total population, 77.6% are 18 years and older and 16% are 65 years and older. Furthermore, out of the population that is 25 years and older, 26.7% have obtained a high school or equivalent degree, 20.3% have completed some college without a degree, 8.6% have obtained a 2-year degree, 20.2% have obtained a 4-year degree and 12.7% have obtained an advanced degree. Additionally, 40.42% of the population was employed as of 2020, with a median household income of $64,994. Over 90% of United States households contain a computer from 2016-2020, and 85.2% have a broadband internet subscription.

COVID-19 Impacts

Following the 1918 influenza virus (H1N1), 1957 influenza virus (H2N2), 1968 influenza virus (H3N2), and 2009 pandemic flu (H1N1), COVID-19 is the fifth pandemic (Aday and Aday, 2020). The fast spreading illness was deemed a pandemic by the World Health Organization (WHO) on March 11, 2020 and the organization urged nations to prepare and take appropriate action in accordance with the Global Strategic Preparedness and Response Plan (Aday and Aday, 2020). Every industry in the world was affected by the Covid-19 outbreak, however the food industry saw impacts in different ways than other industries because it creates goods necessary for daily life (Aday and Aday, 2020). Never before have capacity reductions impacted as many packaging and processing operations at once (Peel, 2021). Labor shortages brought on by illness or a lack of available workers were another supply disturbance to the food supply chain, as were modifications to the production processes to include social distancing practices (Hobbs,

2021). Nevertheless, both strengths and vulnerabilities in the production chains for beef have been revealed by COVID-19 (Peel, 2021).

The initial wave of effects, which started in mid-March 2020, was brought on by the almost complete suspension of food service (Peel, 2021). Demand for groceries at retail suddenly nearly doubled (Peel, 2021). Due to the limitations, consumers prepare their own meals at home instead of dining out (Aday and Aday, 2020). Additionally, consumers were reluctant to visit marketplaces and supermarkets, and restaurants since they risked contracting COVID-19 in the establishments' (Aday and Aday, 2020; Ortez et al., 2022). Empty shelves were a result of increased consumer demand, and an increase in the price of meat items was a result of a reduction in supply (Aday and Aday, 2020). Due to social distance and restaurant closures, consumers preferred takeout and home delivery choices (Aday and Aday, 2020). Consumers' panic buying and stockpiling behaviors amplified the impact of the shift in food demand to retail outlets. (Hobbs, 2021).

Customers typically gave little thought to how the food on their tables was prepared (Aday and Aday, 2020). The massive infrastructure and labor required to produce a safe and consistent food supply globally have come under scrutiny due to worries about food safety during the global epidemic (Aday and Aday, 2020). A consumer survey conducted in the Unites States (n = 999) by Meixner and Katt (2020) demonstrated that food safety has grown significantly in priority due to the pandemic.

The Covid-19 pandemic has created numerous obstacles for the food industry, including an increase in the consumption of healthy foods to strengthen immune systems, an increase in the need for food safety and security, as well as challenges with food

sustainability (Aday and Aday, 2020). COVID-19 could have transformed the industry by encouraging consumers to demand greater transparency about how their meat is produced, influencing more people to choose organic or grass-fed cuts over less expensive, intensively farmed alternatives, and initiating a shift into the quickly expanding "meat alternative" category (Attwood and Hajat, 2020). The COVID-19 pandemic had a major impact over the past few years, however, it will be years from now until the full public health ramifications and economic effects will be apparent (Meixner and Katt, 2020).

Consumer preferences

Consumer perception of meat is a key issue for the meat industry because it significantly influences its profitability (Troy and Kerry, 2010). In order for processors and retailers to successfully meet customer demands through product development and marketing, it is crucial to understand consumer purchasing preferences for fresh beef (Reicks et al., 2011). When deciding what kind of meat to buy, buyers heavily consider the meat's quality (Glitsch, 2000). Color, fat content, marbling, and drip loss are fundamental quality cues that have a strong relationship with customers' expectations of meat quality (Glitsch, 2000). Without a doubt, how something looks affects how buyers perceive quality and has a significant impact on their purchasing decisions (Carpenter et al., 2001). Color and packaging are two crucial visual cues that affect perceived quality when it comes to beef (Carpenter et al., 2001). When buying fresh beef, shoppers must take into account a vast array of criteria, making it challenging to determine which are most crucial (Reicks et al., 2011). Food culture in developed countries has changed over the past few decades, frequently influenced by both environmental and health concerns,

to a more balanced and wide array of food options, such as organics (Meixner and Katt, 2020). Customers are growing more and more interested in the foods they buy (Hawkins and Mothersbaugh, 2013). While selecting food has traditionally been seen as a low-involvement decision needing little information searching or product evaluation, the rise of food label claims has led to a shift in this perception (Ellison et al., 2017). Customers have a greater desire for certain food features, such as quality, claimed health advantages, or production location, in order to relieve these worries, and they are willing to pay more for these attributes (Meixner and Katt, 2020). Consumers must now prioritize and select through a new set of factors, including food production processes, in addition to the traditional features like brand, price, and shelf life (Ellison et al., 2017). Knowing current preferences as well as the value of marbling and color could assist the beef industry to produce visually appealing products for consumers since their preferences for the visual appearance of beef fluctuates (Killinger et al., 2004).

Color stability is dependent on temperature, packaging, and muscle type (MacDougall, 1982). Extensive research has been conducted regarding color stability and increasing shelf life (Suman and Joseph, 2013). This research centers around attempting to limit waste due to meat being discounted or discarded once it reaches a certain percentage of discoloration (Suman et al., 2014). Consumers associate redness with freshness, therefore, when discoloration occurs, consumer acceptance begins to decline which then plummets their willingness to purchase (WTP) (Carpenter et al., 2001; Feuz et al., 2020). Consumers' WTP can vary depending on their ethnic, economic, and religious backgrounds as well as general preferences (Font-i-Furnols and Guerrero, 2014). Studies have shown that consumers begin to discriminate against meat with 20%

metmyoglobin formation (MacDougall, 1982). This is because other than cost, visual acceptability or attractiveness of a product is the main factor influencing their WTP (MacDougall, 1982).

Not only is the attractiveness of a product a concern for consumers, but so is food safety (Glitsch, 2000). Even though the cherry-red color of meat is not a reliable indicator of safety, not meeting consumer expectations for safe and wholesome meat can lead to a decrease in consumer WTP (Ramanathan et al., 2020). This decline in WTP leads to retailers having to discount or discard discolored products which then leads to a loss in revenue and food waste (Ramanathan et al., 2022). In a study done by Ramanathan et al. (2022), they found that the total loss for discounting or discarding discolored beef was around $3.73 billion. Discolored beef leads to major financial loss for the industry every year as well as tremendous food waste. Most consumers will purchase a red product over a discolored one; therefore, discounts are needed in order to entice a consumer to buy a less attractive product (Ramanathan et al., 2022). Feuz et al. (2020) found that beef with even slight discoloration may need a 50% discount or more for consumers to purchase it. Retailers aim to discount discolored beef before discarding it in order to save revenue and eliminate waste. Therefore, reducing discoloration and improving consumer acceptability is crucial to reducing economic loss (Suman and Joseph, 2013).

Price Impacts

The effect price has on consumer purchasing decisions varies from person to person (Font-i-Furnols and Guerrero, 2014). Price may impact a person's purchasing decisions based on product health, perceived product quality or demographic effects

(Andreyeva et al., 2010). According to an experimental study, by Andreyeva et al. (2010) consumers choose healthier food options when the cost of less healthy alternatives increases, and the cost of healthier food options decreases. These claimed health advantages can make consumers believe that those products are better than others or that they are of higher quality. In addition to claimed health advantages, buyers also consider price as a gauge of quality given the notion that price and quality are positively correlated (Dodds et al., 1991). Customers' mental trade-offs between what they think they will gain from a purchase and what they will give up in exchange for the price determine their perceptions of value (Xia et al., 2004). Higher prices are associated with higher perceived quality and, as a result, a greater willingness to purchase (Dodds et al., 1991). Additionally, a higher price indicates, in monetary terms, what must be given up in order to purchase the good, which can lead to a decreased WTP (Monroe, 1990; Dodds et al., 1991). On the other hand, there is a paradoxical situation that occurs when a product is cheaper than other products similar to it, it could be less desirable because of its suspected inferior quality or more desirable because it is cheaper (Dodds et al., 1991). Therefore, people may refrain from buying a product that is higher or lower than their reference price because they may be skeptical of the product quality (Dodds et al., 1991; Greenleaf, 1995; Tanford et al., 2019). Zeithaml (1988) found that perceived value affects perceived quality, which then affects purchasing behavior. Price-based quality assessments are a sign of consumers' uncertainty and how difficult they think it is to assess meat quality (Font-i-Furnols and Guerrero, 2014).The effect of price on purchasing decisions varies depending on demographic characteristics of the consumer. (Font-i-Furnols and Guerrero, 2014). In a study done by Reicks et al. (2011) women were

more motivated by price than men ($P = 0.01$). Reicks et al. (2011), also discovered that when the number of adults living in the home increased, so did the ratings for how important pricing is. Furthermore, consumers with an income of over $100,000 per year showed the least concern about price (Reicks et al., 2011).

Demographic Impacts

The buying habits of different consumer groups can be significantly influenced by demographic factors (Reicks et al., 2011). Education, race, age, and gender all seem to affect the way people choose and consume their meat (Daniel et al., 2010). The United States continues to be the world's largest consumer of all meat, according to data on food availability, and global meat consumption is rising generally in developed countries (Daniel et al., 2010; Clonan et al., 2016). According to research, there are differences in current patterns of meat consumption among Americans based on several demographic variables, possibly reflecting dietary influences from the cultural, social, geographical, and economic aspects (Daniel et al., 2010). A complex web of interconnected elements, such as culture, taste, price, religion, gender, and socioeconomic status affect meat consumption (Clonan et al., 2016). Gender can impact red meat consumption with studies that report women consume less red meat than men (Clonan et al., 2016; Ritzel and Mann, 2021). Health, environmental and animal welfare concerns impact consumer purchasing decisions and can have a negative impact on the meat industry (Clonan et al., 2016). Consumers level of education about meat products can also impact their meat intake (Ritzel and Mann, 2021). The consumption of meat and animal products depends on socioeconomic, ethical, and religious considerations as well as on tradition (Font-i-Furnols and Guerrero, 2014).

The acceptance of meat depends on cultural factors, personal experience, or consumption patterns (Font-i-Furnols and Guerrero, 2014). When choosing food items, low-income consumers must take into account a number of criteria, such as quantity, price, quality, and nutritional variations (Leibtag and Kaufman, 2003). Furthermore, low-income consumers have a variety of strategies to stretch their food budgets: they can shop at discount grocery stores, buy and consume less food than consumers with higher incomes, buy cheap (and potentially inferior) food goods, or use a mix of all three (Leibtag and Kaufman, 2003). The final link in the production process is the consumer, and satisfying their expectations is crucial to their satisfaction and purchasing habits. Therefore, it is critical to understand the elements influencing consumer behavior (Font-i-Furnols and Guerrero, 2014).

Conclusion

Many factors can influence consumers' purchasing decisions. Past research indicates that the main factors that influence purchasing decisions are price, safety, and quality attributes. Of the quality attributes, meat color has a significant effect on whether a consumer will purchase the product or not. The color of beef products changes depending on many factors including the state of the myoglobin. Meat color can vary from purple, to red, or brown, however, consumers typically prefer a bright cherry red color. Many different technologies are used by researchers to determine meat color and acceptability including visual color scoring and spectrophotometers. As technology advances researchers are attempting to pinpoint more specific time frames that consumers deem meat to be unacceptable. To increase meat product sales and inform consumers, it

is crucial to understand consumer purchasing behavior and the factors that influence it more effectively.

CHAPTER III

THE USE OF TIME-LAPSE VIDEO SURVEILLANCE TO EVALUATE MEAT COLOR

ABSTRACT

Consumers' perceptions of quality and purchasing decisions are significantly influenced by appearance. When beef is displayed in stores, it will oxidize and change from oxymyoglobin to metmyoglobin. Customers commonly favor a bright cherry red color since it is thought to be fresher, while dark red or brown is typically viewed negatively. To ascertain whether a consumer will discriminate against a product, color scoring is frequently used. One goal of this study was to evaluate how time-lapse technology could be utilized for color scoring the longissimus lumborum (LL) muscle. Eight USDA Low Choice strip loins, LL, were purchased from a commercial facility. They were aged for 14 d postmortem, sliced into 2.54 cm thick steaks, and randomly assigned to: proximate analysis, lipid oxidation/pH analysis, instrumental color measurement, time-lapse video surveillance, and photography. The other half of the 14 d aged loins were then vacuum packaged and allowed to age until 28 d postmortem. The 28 d aged half loins were then sliced into 2.54 cm thick steaks assigned to photography,

video surveillance, and instrumental color measurement. For both aging times the steaks utilized for instrumental color measurement, time-lapse video surveillance and photography were packaged in trays with polyvinyl chloride overwrap and placed in retail display until they reached 100% discoloration. Steaks assigned to photography were photographed using a Canon EOS R camera every day during display. The Lapse it © software from the Apple App Store was used to record time-lapse video surveillance. Each steak was placed in the retail case under an iPad, allowing it to be recorded in a clear and consistent manner. Until the steak was completely discolored, the App was set to take a recording every hour and was examined often. The 28 d aged steaks were rated on a hedonic scale for visual color, surface discoloration, and overall acceptability by a panel that had been trained and passed the Farnsworth-Munsell 100-hue test. Both panels examined the steaks at the same time every day, with one trained panel evaluating the steak throughout display, while another trained panel evaluated the steak via video surveillance. Visual color was rated using a hedonic scale of 1-8 (1= extremely bright cherry red and 8 = extremely dark red), surface discoloration was rated using a 1-6 (1 = no discoloration, 0%, and 6 = extensive discoloration, 81-100%), and overall acceptability was rated using a 1-7 (1 = very definitely would not purchase and 7 = very definitely would purchase). The GLIMMIX Procedure of SAS was used to determine the least-square means of the color score results on each day, while the CORR procedure determined the correlation between the trained panel and video color scores. $P < 0.05$ was considered significant. There was a significant difference ($P < 0.05$) between the visual color on each retail day. The color score decreased every day until d 7. Moreover, the trained panelists stated they would no longer purchase after d 3, at 21-40% discoloration

with an average *a** value of 29.3. Overall, both panels showed a similar shift in color and acceptability as the length of time in retail display rose. The current study suggests that the use of time-lapse video has the potential to characterize color changes and can be used when an in-person panel is not available. The same materials and methods were used for the half of the loins aged for 14 d postmortem. Once video surveillance was complete for the 28 d aged steaks 3 were selected based on the consistency and clarity of the videos. These videos were then placed in a survey approved by Oklahoma State Universities International Review Board. The survey was distributed via email and social media. The survey was taken by 1,080 participants and consisted of two sections: a demographics section and a video section (three videos). Respondents were asked to determine at which point they would expect a discount or stop purchasing the products in the videos. The GLIMMIX Procedure of SAS was used to determine the least square means of the main effect (video). There was a significant difference ($P < 0.05$) between the responses to the three videos. On average the respondents stated they would expect a discount between 100-107 h of retail display and stop purchasing between 157-164 h of retail display. In conclusion, video color scoring could be a vital tool for researchers to determine the acceptability of beef products at every hour of retail display.

INTRODUCTION

Consumer purchasing decisions can be affected by many factors such as religion, culture, beliefs, product price and perceived quality (Font-i-Furnols and Guerrero, 2014). Consumers perceptions of quality are influenced by appearance, which is one of the most important elements influencing purchasing decisions (Corlett, 2021). When beef is displayed in stores, it will oxidize and change from oxymyoglobin to metmyoglobin

(Mancini and Hunt, 2005). Consumers favor a bright cherry red color (oxymyoglobin) and link it with freshness, while dark red or brown (metmyoglobin) colors are disliked (Mancini and Hunt, 2005). Studies have shown that consumers begin to discriminate against meat with 20% metmyoglobin formation (Macdougall, 1982).

The evaluation of color is crucial to research, product development and identify potential industry problems (AMSA, 2012). It is important to utilize objective and subjective color measurement to obtain the full picture of the product (Warner, 2014). Typical ways to measure color is with a color spectrophotometer in conjunction with trained panelist color scoring (Tomasevic et al., 2021). Researchers must work to pinpoint consumers purchasing preferences; however, theses preferences can change depending on the economy, the political climate of the world and consumers ever changing beliefs (Reicks et al., 2011). It is especially crucial to determine their purchasing decisions in relation to discoloration to eliminate economic loss and food waste (Suman et al., 2014). The characteristic of cherry-red color isn't a reliable predictor of safety, however, failing to achieve customer expectations for safe and healthy meat can result in financial losses and waste (Ramanathan et al 2020). Although, we cannot predict safety by evaluating meat discoloration, many consumers link color with wholesomeness and freshness. Therefore, meat color research is very crucial to determining retail acceptability.

Color scoring is a tool that is widely used to indicate when a consumer would discriminate against a product (AMSA, 2012). Previously researchers were only able to color score in-person and it is difficult to color score multiple times per day. A product can begin to discolor in a short period of time so acceptability can change rapidly and

therefore may be missed with in-person color scoring. These limitations make it hard to find the exact time, within in hours, a product starts to discolor. Using video surveillance, we can use the same products for both trained panel color scoring as well as consumer color scoring. As well as use the same products for future research without having to replicate old studies. As technology continues to improve our ability to assess discoloration and consumer preferences also improves. The objective of this study was to compare the utilization of time-lapse video technology and traditional in-person color scoring of the *longissimus lumborum* (LL) muscle in retail display as well as analyze consumers purchasing decisions.

MATERIALS AND METHODS

Collection

Eight USDA Low Choice strip loins (*Longissimus Lumborum*) were obtained from a commercial beef processing facility (Creekstone Farms; Arkansas City, KS). The strip loins were vacuum packaged and transported on ice to Robert M. Kerr Food and Agricultural Products Center on the Oklahoma State University campus (Stillwater, OK). Two ageing periods were utilized in this study: 14 d and 28 d postmortem. After aging 14 d postmortem in a vacuum package bag (3-mil high barrier Cryovac vacuum bags, Sealed Air-Cryovac, St. Louis, MO) each loin was removed and sliced starting at the anterior end into 5, 2.54 cm thick steaks using a gravity slicer (model SE-12, (Bizerba USA INC., Piscataway, NJ). The other half of each loin was placed in individual vacuum package bags (3-mil high barrier Cryovac vacuum bags, Sealed Air-Cryovac, St. Louis, MO) and stored in dark storage at -1.0°C ± 0.25°C until 28 d. After 14 d postmortem the face steak (most anterior) was utilized for proximate analysis, and the face steaks (most anterior) of

the loins aged for 28 d postmortem were discarded. For each aging period, the second steak was used for lipid oxidation and pH analysis. After the steaks were allowed to bloom in ambient air for 1 h, the remaining 3 steaks were randomly assigned to either instrumental color measurement, time-lapse video surveillance, or photography for both aging periods.

Packaging and storage

After slicing, the three steaks from each loin assigned to instrumental color measurement, time-lapse video surveillance or photography were placed in a 2P Black Processor Styrofoam tray with an absorbent pad (Product number: 63P902P, Material Type: PS – FOAM, Color: Black, Dimensions: 8 X 5.75 X 1.2 IN) packaged with polyvinyl chloride overwrap and placed in simulated retail display setting until they reached 100% discoloration. The steaks were placed in coffin-style Hussmann IM1SL retail cases that had an average temperature of 2.2°C ± 2°C for the entirety of the study. Retail cases were lit with Philips LED T8 Lamps (model number 9290011240B-453597, Color Rendering Index 82, manufactured in Niles, OH). Both retail lights and ceiling lights within the retail room remained on for 24 h/d throughout the entire length of the study. The 14 d aged steaks were in retail display for 11 d, and the 28 d aged steaks were in retail display for 7 d.

Proximate analysis

Proximate analyses were conducted after 14 d of aging to determine the percentages of protein, fat, and moisture of the face steak (most anterior) from each strip loin. All subcutaneous fat and connective tissue were removed before analysis. Each

sample was ground, utilizing a tabletop grinder (Big Bite Grinder, 4.5 mm, fine grind, LEM). The ground samples were tightly packed in a 140-mm sample cup and analyzed using an AOAC approved near-infrared spectrophotometer (FoodScan Lab Analyzer, Serial No. 91753206, Foss, NIRsystem Inc., Slangerupgade, Denmark, 2014).

pH

Muscle pH was measured on the second steak from each loin (anterior end) both at the beginning and end of retail display using a portable pH meter (HANNA Instruments HI99163 Meat pH Meter; Smithfield, RI). At three different internal locations pH was measured.

Thiobarbituric Acid-Reactive Substances (TBARS)

Utilizing a modified version of Witte et al. (1970) methodology, the evaluation of lipid oxidation was done both at the start and the conclusion of retail display for both aging periods. A 3 g sample consisting of only the *Longissimus Lumborum* Muscle of each of the eight steaks was taken and mixed with a 27 mL solution of trichloroacetic acid (TCA). Using a Waring commercial blender (Model 33BL7; New Hartford, CT) samples were blended for 10 s before being filtered through Whatman (#1) filter paper. 1 mL of thiobarbituric acid (TBA) solution and 1 mL of filtered solution were combined and placed in a boiling water bath for 10 m. Following incubation, samples were cooled at room temperature for 5 m, after which absorbance was determined at 532 nanometers using a Shimadzu UV-2600 PC spectrophotometer (UV-2600, UV–VIS Spectrophotometer, Shimadzu, Columbia, MD).

Video Surveillance

The 8 steaks assigned to video surveillance were placed in the retail case under each Apple iPad mini (5th-generation, 8-megapixel camera), to take clear and consistent recordings. The iPad was set on a Tablet Mount (Lamicall Flexible Arm Clip) to position the iPad over the retail case and each specific steak. The distance from the iPad camera to the surface of the steak was approximately 36 cm. Time-lapse video surveillance was taken using the Lapse It© app from the Apple App Store. The app was set to record every hour and was checked periodically until d 11 for the 14 d aging period and until d 7 for the 28 d aging period.

Instrumental color measurement

A portable, reflected-color measurement spectrophotometer was used to quantitatively measure instrumental color. The HunterLab MiniScan® EZ 4500L (2.5-cm aperture, illuminant A, and 10° standard observer angle; Reston, VA, USA) was used to take measurements in triplicate at random spots on the surface of each steak assigned to instrumental color measurement. Prior to each use, the HunterLab MiniScan instrument was standardized using white and black tiles. Throughout retail display, measurements were taken immediately after bloom, and every 24 h for the entirety of the study (11 d for the 14 d aging period and 7 d for the 28 d aging period) and readings were then averaged. Values of L^* quantify lightness from white to black and higher L^* values denote lighter products. Values of a^* measure red to green color and are used to quantify how red a product is. Higher a^* values indicate a redder product. Values of b^* values were used to quantify blue to yellow color with positive b^* values indicating yellow color and negative b^* values indicating blue color.

Photography

The 8 steaks assigned to photography were removed from the case at the same time each day, the polyvinyl chloride overwrap was removed, and a photo was taken. After the steak was photographed it was re-wrapped with new film and placed back into the case. A photo was taken every day for 11 d for the 14 d aging period and 7 d for the 28 d aging period. The distance from the bottom of the camera lens to the steak surface was 31 cm. All photos were taken from the same distance and with a matte black background. The lens was a Canon 24-105mm. For the camera settings, ISO was set to auto and the shutter speed was 1/80 and the aperture was at F11.

Color Scoring

During video surveillance, an 8-member trained panel all of whom passed the Farnsworth-Munsell 100-Hue Test and trained following the American Meat Science Association meat color guidelines, evaluated the 28 d aged steaks for visual color, surface discoloration, and overall acceptability using a hedonic scale for each. Throughout the display, trained panelists evaluated the steak in person, and a separate trained panel evaluated the steak from the video surveillance after the 7 d was completed. Both panels evaluated the steak at the same time each day for the 7 d. Visual color was rated using a hedonic scale of 1-8 (1= extremely bright cherry red, 2= bright cherry red, 3= moderately bright cherry red, 4= slightly bright cherry red, 5= slightly dark cherry red, 6= moderately dark red, 7= dark red, 8 = extremely dark red), surface discoloration was rated using a 1-6 (1 = no discoloration, 0%, 2 = slight discoloration, 1-20%, 3 = small discoloration, 21-40%, 4 = modest discoloration, 41-60%, 5 = moderate discoloration, 61-80%, and 6 =

extensive discoloration, 81-100%), and overall acceptability was rated using a 1-7 (1 = very definitely would not purchase, 2 = definitely would not purchase, 3 = probably would not purchase, 4 = may or may not purchase, 5 = probably would purchase, 6 = definitely would purchase, 7 = very definitely would purchase).

Consumer Survey

Once time-lapse video surveillance of 14 d aged steaks was completed on d 11, the videos of each steak were accelerated to 30 s, edited, and the three that discolored at the most similar rate were selected for use in a consumer survey. These videos were then cropped to for best viewing and uploaded to the consumer survey via a YouTube link. The survey was created using the survey platform Qualtrics (Qualtrics 2017) and was distributed through email and social media links. This survey was approved by Oklahoma State Universities International Review Board (IRB -22-286). It was available from August 1^{st,} 2022, through September 26th, 2022. The survey was taken by 1,080 participants, and the target sample was chosen to be representative of the population of the United States.

The survey consisted of two sections. A demographics section and a video section (three videos). The demographics section consisted of a consent form followed by 13-17 demographic questions. Questions were directed based on answers to specific questions (Appendix C). Once the consumer finished the demographics section the survey either ended or prompted them to three, 30 s time-lapse videos.

Statistical analysis

The PROC GLIMMIX procedure of SAS 9.4 (SAS Institute Inc., Cary, North Carolina), was utilized for the color scoring results, where the main effects were color scoring method, day, and their interactions. Non-significant interactions were removed from the model. Least square means were calculated; where ANOVA testing indicated significance, means were separated using the PDIFF option and deemed significant when $P < 0.05$. The PROC CORR procedure was then used to find the correlation coefficients for visual color, surface discoloration and overall acceptability between in-person and video color scoring.

The FREQ procedure of SAS 9.4 (SAS Institute Inc., Cary, North Carolina), was utilized to determine percentages and frequencies of responses for the demographic portion of the consumer preference survey.

The GLIMMIX procedure of SAS 9.4 (SAS Institute Inc., Cary, North Carolina), was used to analyze the responses to the video questions, where the main effect was video number. Least square means were calculated; where ANOVA testing indicated significance, means were deemed significant when $P < 0.05$.

RESULTS AND DISSCUSSION

Proximate Analysis and pH

Proximate analyses were conducted on the face steak of each strip loin and those are shown in Table 1. The averages for protein, fat, and moisture were 23.17%, 5.77%, and 72.50% respectively. The averages of protein, moisture, and fat were comparable to USDA low-choice strip steaks used in other research studies (O'Quinn et al., 2012;

Legako et al., 2015). The mean pH for all steaks on the initial and final days of retail display was 5.48 which falls within the normal pH range for fresh beef (Page et al., 2001; Viljoen et al., 2002).

Thiobarbituric Acid-Reactive Substances (TBARS)

Lipid oxidation was affected by retail day and aging period. There was a significant effect of retail day on lipid oxidation ($P < 0.05$). Least square means and standard error of the mean were conducted and shown in Table 2. Lipid oxidation increased from initial retail day to final retail day. Various elements, including the presence of light, oxygen exposure, and temperature accelerate oxidative processes (Jakobsen and Bertelsen, 2000; Domínguez et al., 2019). As time in retail display increases so does exposure to light and oxygen, thus increasing lipid oxidation. There was also a significant effect of aging period on lipid oxidation ($P < 0.05$). Ismail et al. (2008) found that lipid oxidation increased with longer aging periods. Lipid oxidation is one of the main reasons for decreased quality in meat products (Min and Ahn, 2005; Ismail et al., 2008; Domínguez et al., 2019). The consumer's ability to recognize the oxidation products that cause rancidity or changes in meat color is what determines the meat's shelf life (Domínguez et al., 2019).

L* **values**

There was a significant effect of day on L^* values for the 14 d and 28 d aging periods ($P < 0.05$) (Table 3). Steaks with a 14 d aging period, L^* values fluctuated from d 1 to d 5 and then began to decrease from d 5 through d 11, and color was the lightest on d 0 and darkest on d 9-11 ($P < 0.05$). Steaks with a 28 d aging period showed a decrease in

*L** values until d 4. *L** values increased on d 5 and then decreased every day until d 7. Color was the lightest on d 1 and darkest on d 7 ($P < 0.05$). Steaks aged for 14 days postmortem had a lower numerical *L** value (37.69) on the final day of retail display (d 11) than steaks aged for 28 days postmortem (39.36) on their final day of retail display (d 7) ($P < 0.05$) Perry (2018) found a similar decrease in *L** values over retail display.

*a** values

There was a significant effect of day on *a** values for the 14 d (Table 4) and 28 d aging periods (Table 4). For steaks with a 14 d aging period, *a** values increased from d 1 to d 2 and then decreased every day from d 2 to d 11. For steaks with a 28 d aging period, *a** values decreased every day from d 1 to d 7. This indicates that the steaks in both aging periods decreased in redness as days in retail display increased. Steaks aged for 14 days postmortem had a slightly lower numerical *a** value (16.82) on the final day of retail display (d 11) than steaks aged for 28 days postmortem (16.94) on their final day of retail display (d 7). This could be attributed to more days on retail display. Furthermore, steaks with a 28 d aging periods' *a** values declined more rapidly than steaks with a 14 d aging period. Karney et al. (2022) found similar results of a decrease in *a** values as aging and display time increased.

Visual Color

There was a significant effect of day on visual color ($P < 0.05$). Least square means and the correlation coefficient of in-person and video color scoring were conducted for visual color as shown in Table 5. Visual color decreased every day for 7 d.

Other researchers also show muscle color scores decreased on each storage day, and the vivid cherry red color became less prominent (Harlan, 2012). Visual color started at extremely bright cherry red and did not exceed slightly dark cherry red over the course of 7 d. Consumers associate bright cherry red color with freshness therefore as color diminishes so does their willingness to purchase (Feuz et al., 2020). Most consumers prefer a bright cherry red color to a dark red color (Font-i-Furnols and Guerrero, 2014). However, according to research done by (Killinger et al., 2004), some consumers prefer a darker red color because they associate it with aging and tenderness of the product. Consumer preferences and purchasing decisions can differ based on their background, beliefs, and expectations, as well as product price, and marketing schemes (Font-i-Furnols and Guerrero, 2014). Nevertheless, visual color remains the first-factor consumers see and base judgment upon. There was no significant effect of the interaction between in-person and video color scoring for visual color (P= 0.945). Therefore, video color scoring can be used in conjunction with, or as a replacement for in-person color scoring.

Surface Discoloration

There was a significant effect of day on surface discoloration ($P < 0.05$). Least square means and the correlation coefficient of in-person and video color scoring were conducted for surface discoloration as shown in Table 6. Surface discoloration started at no discoloration (0%) and increased to modest discoloration (41-60%) by d 7. For video and in-person color scoring the steaks remained at 0 % discoloration from d 1 until d 4 and discoloration increased every day until d 7. Other research has shown steaks become

discolored after being exposed to residual oxygen for an extended period; this causes the production of metmyoglobin, which gives the meat a brown appearance (Suman and Joseph, 2013). This brown appearance decreases a consumer's willingness to purchase. Therefore, steaks that discolor more than consumer acceptability levels will be discounted or discriminated against (Smith et al., 2000). Additionally, consumers will discount a product at 20% discoloration and completely reject the product when discoloration reaches 40% (McMillin, 2008). This same trend is shown in Tables 3 and 4. As surface discoloration reaches 21-40% the trained panelists stated they probably would not purchase the product. However, since this is a trained panel of color scorers, consumer acceptability may differ. There was no significant effect of the interaction between in-person and video color scoring for surface discoloration ($P = 0.639$). Therefore, video color scoring can be used in conjunction with, or as a replacement for in-person color scoring.

Overall Acceptability

There was a significant effect of day on overall acceptability ($P < 0.05$). Least square means and the correlation coefficient of in-person and video color scoring were conducted for overall acceptability as shown in Table 7. Overall acceptability remained positive until d 4 where the color scoring panel stated they may or may not purchase. However, after d 4 acceptability continues to decrease until d 7. This follows the trend of visual color and surface discoloration. As time in retail display increases overall acceptability decreases. Other researchers have shown overall acceptability affects consumers' willingness to purchase (Smith et al., 2000). This is because consumers

prefer a bright cherry red product with no discoloration; therefore, visual appearance is the primary limiting factor in purchasing decisions (Smith et al., 2000). Percentages of muscle color and discoloration indicate overall acceptance (Isdell et al., 2003). The results of this study are consistent with studies suggesting that steaks with lower visual color scores and discoloration percentages are less popular among consumers (Smith et al., 2000; Isdell et al., 2003). The high correlation between visual and in-person color scoring shows that video color score could be used as a tool to determine visual color, surface discoloration, and overall acceptability when in-person color scoring is not available. Video color scoring can also be used to identify specific hours of retail display that would not normally be evaluated by a trained or consumer color scoring panel. There was no significant effect of the interaction between in-person and video color scoring for overall acceptability (P= 0.988). Therefore, video color scoring can be used in conjunction with, or as a replacement for in-person color scoring.

Consumer preference survey

Demographic results for the consumer preference survey are shown in Tables 8 and 9. In total 1,080 participants responded to the survey. Responses were recorded from all 50 states with 51.3% being from Oklahoma. Biological sex was sorted into 3 categories: male (34.6%), female (65.0%), and prefer not to specify (0.37%). According to the U.S. Census Bureau (2020), the U.S. population is 50.5% female. Moreover, according to Singer et al. (2000), women are more likely to participate in surveys than men. Furthermore, half of the participants were between the ages of 21 and 35 years of age (51.9%). Also, 61.5 % of respondents were employed full time with 36% having a

household income of $100,000 or more. When asked the highest level of education they had completed, 70% of respondents had completed a four-year degree or advanced degree. Curtin et al. (2000) found that people that are more educated are more likely to participate in surveys than less educated people. Compared to the United States Census (2020), our sample had a slightly higher employment rate and a higher average education level. Additionally, 88.6% of respondents selected caucasian as their ethnic background compared to 75.8% from the U.S. Census (2020). Respondents were also asked to select which level best describes their knowledge of the animal agriculture and meat industries. 31.6% stated they were very knowledgeable about the animal agriculture industry, and 34.3% said they were somewhat knowledgeable about the meat industry. The answer to those two questions could have impacted how they answered the rest of the questions in the survey.

The secondary part of the survey was related to consumers' purchasing habits. The results from these questions are in Table 10. When asked if they were the primary shopper in their household, 63.9% of respondents said yes, 11.7% said no and 24.4% said they shared equally in food purchasing responsibility. How the respondents answered to the rest of the questions determined the other questions they were asked. If they stated that they do not purchase meat (4.4%) or beef (2.9%), they were directed to a question requesting them to indicate the reasons they do not purchase meat or beef (multiple options could be selected). Of these 78.4% (37 respondents) selected other as their reasoning for not purchasing meat while other respondents stated that price (21.6%), environmental impact (21.6%), ethical reasons (21.6%), animal welfare (16.2%), or religious reasons (2.7%), were responsible. When asked why they do not purchase beef,

12.9% of 31 respondents stated that price was the reason, while other respondents stated that environmental impact (6.5%), ethical reasons (9.7%), animal welfare (9.7%), or religious reasons (3.2%). The majority of respondents selected other as their reasoning for not purchasing beef (62.5%), and some opted to specify why they chose other; 5 do not purchase beef because of health reasons, 2 because of taste preferences, 10 because they raise their own beef, 1 stated they were raised vegan. Additionally, if they did not purchase meat they were asked if they purchase any meat substitutes; 24.3% purchase veggie burgers, 21.6% purchase tofu, and 13.5% purchase either beyond or impossible meat products, and 75.7% chose the other option. After responding to those questions if the consumers did not purchase meat or beef their survey ended.

If they stated that they do purchase meat (95.7%), they were asked to select which of the following meats they purchase (multiple options could be selected); beef (96.9%), chicken (95.8%), pork (83.8%), lamb (15.2%), fish or seafood (65.4%). Of beef consumers, 41.6% said they purchase beef at least once per week and when purchasing beef 80.62% stated they typically purchase beef that is traditionally or conventionally raised or processed. Furthermore, when asked the number one factor influencing their purchasing decisions, the top 3 responses were price (38.9%), USDA grade or marbling (33.6%), and color (8.4%). Also, 25.9% of respondents said they consume beef at least 3 times per week at home and 36.1% stated they consume beef at least 1 time per week at a restaurant or fast-food establishment.

Many factors can affect consumers purchasing decisions such as price, color, marbling, weight, number of products included in a package, and availability. Within

these factors, demographic characteristics also play a role (12). Most of both males and females stated that price was the top influencer when purchasing beef followed by USDA Grade (marbling). Additionally, price was the top influencing factor among respondents aged 18-55, and USDA grade was the top influencer among respondents ages 56 and above. Household income also played a role in what influences respondents to purchase beef. Many respondents with a household income of $74,999 and below stated that price was their main purchasing influencer. Most respondents with a household income of $75,000 and above stated that USDA Grade was their main purchasing influencer.

Furthermore, knowledge of the animal agriculture and meat industries also impacted purchasing influencers. Most respondents who stated they were somewhat, slightly, or not knowledgeable about the animal agriculture industry selected price as their number one purchasing influencer and most respondents who stated they were very or extremely knowledgeable selected USDA grade as their number one influencer (Table 12). Most respondents who stated they were not knowledgeable about the meat industry selected price as their number one purchasing influencer followed by color. Most respondents who stated they were not slightly or somewhat knowledgeable about the meat industry selected price as their number one purchasing influencer followed by USDA grade. Most respondents who stated they were very or extremely knowledgeable selected USDA grade as their number one influencer followed by price.

Demographic characteristics also play a role in purchasing decisions. Most of both males (289) and females (491) stated they purchased traditional/conventional beef, followed by locally sourced (Table 11). Additionally, traditional/conventional was the most popular across all age groups, education levels, and household incomes.

Furthermore, knowledge of the animal agriculture and meat industries also impacted purchasing influencers. As knowledge about the animal agriculture industry increased, number of respondents that stated they purchased organic beef decreased.

After completing all demographic and purchasing habits questions, respondents were asked to evaluate 3-time lapse videos of strip loin steaks in a retail case. After watching each video, respondents were asked to select at which second in the video they would expect a discount for the product and at which second, they would stop purchasing the product. The average time points are shown in Table 14 and Figure 5. For the first video, 844 responses were recorded and the mean time point for expecting a discount was 13.87 seconds which would correlate to hours 100-107 in the retail case. This was on d 5- d 6 from 8:30pm-3:30am. The mean time point for the consumer to stop purchasing was 18.24 seconds which would correlate to hours 140-147 in the retail case. This was on d 7 from 12:30 pm-7:30 pm. For the second video, 815 responses were recorded and the mean time point for expecting a discount was 13.19 seconds which would correlate to hours 100-107 in the retail case. This was on d 5- d 6 from 8:30 pm-3:30 am. The mean time point for the consumer to stop purchasing was 17.2 seconds which would correlate to hours 132-139 in the retail case. This was on d 7 from 4:30 am-11:30 am. For the third video, 786 responses were recorded and the mean time point for expecting a discount was 12.11 seconds which would correlate to hours 92-99 in the retail case. This was on d 5 from 12:30 pm-7:30 pm. The mean time point for the consumer to stop purchasing was 15.83 seconds which would correlate to hours 116-123 in the retail case. This was on d 6 from 12:30 pm-7:30 pm.

We speculate that the reasons for these differences are respondent error, screen brightness, and discoloration rate. The time frame for the consumers to expect a discount or stop purchasing is not the typical time point that color scoring is conducted, especially for consumers. This can create problems for research because they cannot color score in-person at every hour of the day. Utilizing new technology such as time lapse video surveillance can help researchers conduct shelf life research continuously. It is especially helpful when using a consumer panel because it is more difficult to have consumers come in multiple times a day to view and score the products or throughout the night. Additionally, the ability to reach a much larger more diverse consumer group is achieved via video.

Furthermore, how critical a person is about the beef they buy can be impacted by their demographic characteristics such as biological sex, age, education level, household income and knowledge of the animal agriculture and meat industries. This is shown in Table 13. Females had a smaller time interval between expecting a discount and stop purchasing than males. Ages 56-65 had the largest time interval between expecting a discount and stop purchasing. Respondents with a highest degree earned of high school or equivalent expected a discount and stopped purchasing earlier than other respondents with higher degrees earned. Additionally, respondents who stated they were not knowledgeable about the animal agriculture industry expected a discount at 11 s and those who were extremely knowledgeable would expect a discount at 14 s (Figure 1). Respondents who stated they were not knowledgeable about the animal agriculture industry would stop purchasing the product at 14 s and those who were extremely knowledgeable would stop purchasing the product at 18 s (Figure 2). Moreover,

respondents who stated they were not or slightly knowledgeable about the meat industry expected a discount at 11 s, and respondents who stated they were somewhat, very, or extremely knowledgeable about the meat industry expected a discount at 13s (Figure 3). Lastly, respondents who stated they were not knowledgeable about the meat industry would stop purchasing the product at 14 s and respondents who stated they were very or extremely knowledgeable about the meat industry would stop purchasing the product at 18s (Figure 4).

CONCLUSION

Many factors influence consumers purchasing decisions including price, USDA grade, and color. It is important to understand what motivates consumers purchasing decisions to better market and sell beef products. Continuing to advance in research regarding consumers is crucial to the meat industry because consumers' buying habits and priorities are continually changing. These changes can be brought on by politics, marketing schemes, the economy, and personal beliefs, or preferences. By utilizing new technology researchers can better understand the minds and preferences of consumers and continue to educate and feed the world.

Table 1. Proximate Analysis measurements for protein, moisture, and fat, of all USDA Choice beef strip loins

Steak Number	Protein %	Fat %	Moisture %
101	23.42	4.93	73.18
201	23.01	4.80	73.84
301	22.65	4.83	73.56
401	23.07	6.97	71.41
501	22.92	7.07	71.29
601	22.64	5.95	72.79
801	23.78	5.33	72.87
901	23.85	6.29	71.06
Averages[1]	23.17	5.77	72.50

[1]Averages for all loins

Table 2. Least square means of thiobarbituric acid reactive substance[1] values for USDA Choice strip steaks aged 14 d and 28 d postmortem on initial and final retail display days

Aging period	Initial retail day	Final retail day
14	$0.36^{b,z}$	$0.72^{a,z}$
28	$.0.45^{b,y}$	$1.06^{a,y}$
	SEM[2]= 0.05	

[1]Reported in mg/ malondialdehyde

[2] SEM = Standard error of the mean

[a-b] Least square means that do not share a common subscript within rows are significantly different ($P < 0.05$)

[z-y] Least square means that do not share a common subscript within columns are significantly different ($P < 0.05$)

Steaks aged for 14 d postmortem were in retail display for 11 d

Steaks aged for 28 d postmortem were in retail display for 7 d

Table 3. Least square means for L^*[1] from strip loin steaks aged for 14 days postmortem (n= 8 steaks) and on retail display under normal conditions

		Retail day											
	Aging period	1	2	3	4	5	6	7	8	9	10	11	SEM[2]
L*	14	44.88^{a}	42.40^{bc}	42.52^{b}	41.56^{bcd}	42.00^{bcd}	41.02^{bcd}	40.48^{cde}	40.22^{de}	38.93^{ef}	37.73^{f}	37.69^{f}	0.68
	28	44.72^{a}	43.59^{ab}	42.90^{b}	42.77^{b}	43.88^{ab}	41.14^{c}	39.36^{d}	-	-	-	-	0.52

[1] L* values: higher values indicate a lighter color

[2] SEM = Standard error of the mean

[a-d] Least square means that do not share a common subscript within rows are significantly different ($P < 0.05$)

Steaks aged for 14 d postmortem were in retail display for 11 d

Steaks aged for 28 d postmortem were in retail display for 7 d

Table 4. Least square means for a^*[1] from strip loin steaks aged for 14 and 28 days postmortem (n= 8 steaks) and on retail display under normal conditions

		Retail day											
	Aging period	1	2	3	4	5	6	7	8	9	10	11	SEM[2]
a*	14 d	$31.18^{ab,vwx}$	$33.87^{a,v}$	$32.56^{a,vw}$	$32.55^{a,vw}$	$31.63^{ab,vwx}$	$31.37^{ab,vwx}$	$29.33^{bc,x}$	27.33^{c}	22.53^{d}	17.88^{e}	16.82^{e}	1.05
	28 d	$33.88^{a,v}$	$32.64^{ab,vw}$	$30.35^{ab,wx}$	$29.34^{bc,x}$	$26.08^{c,y}$	$19.67^{d,z}$	$16.94^{d,z}$	-	-	-		1.36

[1] a* values: higher values indicate a redder color

[2] SEM = Standard error of the mean

[a-d] Least square means that do not share a common subscript within rows are significantly different ($P < 0.05$)

[v-z] Least square means that do not share a common subscript within columns are significantly different ($P < 0.05$)

Steaks aged for 14 d postmortem were in retail display for 11 d

Steaks aged for 28 d postmortem were in retail display for 7 d

Table 5. Least square means and correlation coefficient for visual color for 7 d in retail display from 2 color scoring methods (video and in-person) of strip loin steaks (n = 8)

Retail day	1	2	3	4	5	6	7
Video	1.16[a]	1.80[b]	2.64[c]	3.06[d]	3.64[e]	4.67[f]	5.54[g]
In-Person	1.00[a]	1.78[b]	2.65[c]	2.96[cd]	3.54[e]	4.84[f]	5.52[g]

r^2 = .99

[a-e] Least square means that do not share a common subscript within are significantly different ($P < 0.05$)

Visual color was rated using a scale of 1-8

1 = extremely bright cherry red

2 = bright cherry red

3 = moderately bright cherry red

4 = slightly bright cherry red

5 = slightly dark cherry red

6 = moderately dark red

7 = dark red

8 = extremely dark red

Table 6. Least square means and correlation coefficient for surface discoloration for 7 d in retail display from 2 color scoring methods (video and in-person) of strip loin steaks (n = 8)

Retail day	1	2	3	4	5	6	7
Video	1.00[a]	1.07[a]	1.43[bc]	1.86[d]	2.8[e]	3.37[f]	4.35[g]
In-Person	1.00[a]	1.04[a]	1.26[ab]	1.66[cd]	2.6[e]	3.55[f]	4.38[g]

r^2 = .99

[a-e] Least square means that do not share a common subscript are significantly different ($P < 0.05$)

Surface discoloration was rated using a scale of 1-6

1 = no discoloration, 0%

2 = slight discoloration, 1-20%

3 = small discoloration, 21-40%

4 = modest discoloration, 41-60%

5 = moderate discoloration, 61-80%

6 = extensive discoloration, 81-100%

Table 7. Least square means and correlation coefficient for overall acceptability for 7 d in retail display from 2 color scoring methods (video and in-person) of strip loin steaks (n = 8)

Retail day	1	2	3	4	5	6	7
Video	7.00[a]	6.73[a]	5.93[b]	5.32[c]	4.48[d]	2.92[e]	2.04[f]
In-Person	7.00[a]	6.91[a]	6.09[b]	5.54[c]	4.60[d]	2.97[e]	2.19[f]

r^2 = .99

[a-f] Least square means that do not share a common subscript are significantly different ($P < 0.05$)

Overall acceptability was rated using a scale of 1-7

1 = very definitely would not purchase

2 = definitely would not purchase

3 = probably would not purchase

4 = may or may not purchase

5 = probably would purchase

6 = definitely would purchase

7 = very definitely would purchase

Table 8. Demographic characteristics by state (n=1080)									
Characteristic	Response	Percentage				Frequency			
		Respondents who purchase beef	Respondents who do not purchase beef	Respondents who do not purchase meat	Total Percentage	Respondents who purchase beef	Respondents who do not purchase beef	Respondents who do not purchase meat	Total Frequency
n		1001	32	47	1080	1001	32	47	1080
State[1] (n=1080)	Alabama	1.10	-	-	1.02	11	-	-	11
	Alaska	0.20	-	-	0.19	2	-	-	2
	Arizona	1.00	-	-	0.93	10	-	-	10
	Arkansas	30.00	3.13	2.13	2.96	30	1	1	32
	California	1.60	3.13	2.13	1.67	16	1	1	18
	Colorado	4.30	-	6.38	4.26	43	-	3	46
	Connecticut	0.10	-	-	0.09	1	-	-	1
	Delaware	0.40	-	-	0.37	4	-	-	4
	Florida	5.59	-	-	5.19	56	-	-	56
	Georgia	0.90	-	2.13	0.93	9	-	1	10
	Hawaii	0	3.13	-	0.09	0	1	-	1
	Idaho	0.10	-	-	0.09	1	-	-	1
	Illinois	1.10	-	2.13	1.11	11	-	1	12
	Indiana	0.30	-	-	0.28	3	-	-	3
	Iowa	1.50	-	-	1.39	15	-	-	15
	Kansas	2.10	6.25	-	2.13	21	2	-	23
	Kentucky	0.20	3.13	-	0.28	2	1	-	3
	Louisiana	0.30	-	-	0.28	3	-	-	3
	Maine	0.10	-	-	0.09	1	-	-	1
	Maryland	0.30	3.13	-	0.37	3	1	-	4
	Massachusetts	0.10	-	-	0.09	1	-	-	1
	Michigan	0.40	-	-	0.37	4	-	-	4
	Minnesota	0.10	3.13	-	0.19	1	1	-	2
	Mississippi	0.20	-	-	0.19	2	-	-	2
	Missouri	1.10	-	-	1.02	11	-	-	11
	Montana	0.10	-	-	0.09	1	-	-	1
	Nebraska	2.90	-	-	2.69	29	-	-	29
	Nevada	0.10	-	-	0.09	1	-	-	1
	New Hampshire	0.10	-	2.13	0.19	1	-	1	2
	New Jersey	0.50	-	-	0.46	5	-	-	5
	New Mexico	0.20	-	-	0.19	2	-	-	2
	New York	0.30	3.13	2.13	0.46	3	1	1	5
	North Carolina	0.20	-	-	0.19	2	-	-	2
	North Dakota	0.20	-	-	0.19	2	-	-	2
	Ohio	1.80	-	2.13	1.76	18	-	1	19
	Oklahoma	50.65	46.88	68.09	51.30	507	15	32	554

	Oregon	0.30	6.25	-	0.46	3	2	-	5
	Pennsylvania	0.50	-	-	0.46	5	-	-	5
	Rhode Island	0.10	-	-	0.09	1	-	-	1
	South Carolina	0.60	-	-	0.56	6	-	-	6
	South Dakota	0.40	6.25	-	0.56	4	2	-	6
	Tennessee	0.80	-	-	0.74	8	-	-	8
	Texas	11.89	9.38	4.26	11.48	119	3	2	124
	Utah	0.20	-	-	0.119	2	-	-	2
	Vermont	0.30	3.13	-	0.37	3	1	-	4
	Virginia	0.20	-	-	0.19	2	-	-	2
	Washington	0.60	-	-	0.56	6	-	-	6
	West Virginia	0.10	-	-	0.09	1	-	-	1
	Wisconsin	0.70	-	2.13	0.74	7	-	1	8
	Wyoming	0.20	-	4.26	0.37	2	-	2	4

[1]question above was displayed to all respondents

Table 9. Demographic characteristics from consumer panelists (n=1080)

Characteristic	Response	Percentage				Frequency			
		Respondents who purchase beef	Respondents who do not purchase beef	Respondents who do not purchase meat	Total Percentage	Respondents who purchase beef	Respondents who do not purchase beef	Respondents who do not purchase meat	Total Frequency
n		1001	32	47	1080	1001	32	47	1080
Biological Sex (n=1080)	Female	64.34	75.00	72.34	65.0	644	24	34	702
	Male	35.36	21.88	27.66	34.63	354	7	13	374
	Prefer not to specify	0.30	3.13	0	0.37	3	1	0	4
Age (n=1080)	18-20 years	7.59	6.25	14.89	7.87	76	2	7	85
	21-25 years	30.47	25.00	34.04	30.46	305	8	16	329
	26-35 years	21.28	34.38	14.89	21.39	213	11	7	231
	36-45 years	11.69	6.25	17.02	11.76	117	2	8	127
	46-55 years	11.09	9.38	6.38	10.83	111	3	3	117
	56-65 years	10.49	18.75	6.38	10.56	105	6	3	114
	66 years and older	7.39	0	6.38	7.13	74	0	3	77
Working status (n=1080)	Not employed	9.19	12.50	8.51	19.26	92	4	4	100
	Student	21.88	9.38	34.04	22.04	219	3	16	238
	Part-time	7.29	12.50	2.13	7.22	73	4	1	78
	Full-time	61.64	65.63	55.32	61.48	617	21	26	664
Household Income (n=1080)	Below $25,000	15.38	12.50	14.89	15.28	154	4	7	165
	$25,001 - 49,999	12.49	12.50	29.79	13.24	125	4	14	143
	$50,000 – 74,000	17.28	34.38	12.77	17.59	173	11	6	190
	$75,000 – 99,999	18.18	12.50	14.89	17.87	182	4	7	193
	$100,000 or more	36.66	28.13	27.66	36.02	367	9	13	389
Highest degree earned (n=1080)	High school or equivalent	16.78	12.50	27.66	17.13	168	4	13	185
	Trade school	3.80	0	0	3.52	38	0	0	38
	2-year degree	9.39	6.25	10.64	9.35	94	2	5	101
	4-year degree	42.06	68.75	40.43	42.78	421	22	19	462
	Advanced degree	27.97	12.50	21.28	27.22	280	4	10	294
Ethnic Background (n=1080)	Caucasian		65.63	95.74	88.61	891	21	45	957
	African American	0.08	0	0	0.74	8	0	0	8

	Hispanic	3.70	6.25	2.13	3.70	37	2	1	40
	American Indian	4.30	15.63	2.13	4.54	43	5	1	49
	Asian or Pacific Islander	0.08	12.50	0	1.11	8	4	0	12
	Other	1.40	0	0	1.30	14	0	0	14
Knowledge of the animal agriculture industry (n=1080)	Not knowledgeable	11.09	25.00	6.38	11.30	111	8	3	122
	Slightly knowledgeable	15.08	10.75	8.51	14.91	151	6	4	161
	Somewhat knowledgeable	23.68	21.88	25.53	23.70	237	7	12	256
	Very knowledgeable	30.87	31.25	46.81	31.57	309	10	22	341
	Extremely knowledgeable	19.28	3.13	12.77	18.52	193	1	6	200
Knowledge of the meat industry (n=1080)	Not knowledgeable	12.19	25.00	10.64	12.50	122	8	5	135
	Slightly knowledgeable	20.08	21.88	14.89	19.91	201	7	7	215
	Somewhat knowledgeable	33.67	40.63	42.55	34.26	337	13	20	370
	Very knowledgeable	23.98	12.50	29.79	23.89	240	4	14	258
	Extremely knowledgeable	10.09	0	2.13	9.44	101	0	1	102

All questions above were displayed to all respondents

[1] indicates question was displayed to all respondents

[2] indicates question was only displayed to respondents who purchase beef products

[3] indicates question was only displayed to respondents who do not purchase beef

[4]indicates question was only displayed to respondents who do not purchase meat

Table 10. Purchasing influencers									
Characteristic	Response	Percentage				Frequency			
		Respondents who purchase beef	Respondents who do not purchase beef	Respondents who do not purchase meat	Total Percentage	Respondents who purchase beef	Respondents who do not purchase beef	Respondents who do not purchase meat	Total Frequency
n		1001	32	47	1080	1001	32	47	1080
Are you the primary shopper in your household[1] (n=1080)	yes	64.04	75.00	53.19	63.89	641	24	25	690
	no	10.99	15.63	27.66	11.67	110	5	13	126
	I share equally	24.98	9.38	19.15	24.44	250	3	9	264
Do you purchase meat[1] (n=1080)	yes	100	100	0	95.65	1001	32	0	1033
	no	0	0	100	4.35	0	0	47	47
n		996	32		1028	996	32		1028
Which of the following meats do you purchase[1] (n=1028)	chicken	99.06	87.50	-	95.8	957	28	-	985
	beef	100	0	-	96.9	996	0	-	996
	lamb	15.66	0	-	15.2	156	0	-	156
	pork	84.94	46.87	-	83.8	846	15	-	861
	Fish or seafood	65.46	62.50	-	65.4	652	20	-	672
n			31				31		31
Why do you not purchase beef[3] (n=31)	Price	-	12.90	-		-	4	-	4
	Environmental	-	6.45	-		-	2	-	2
	Religious	-	3.23	-		-	1	-	1
	Ethical	-	9.68	-		-	3	-	3
	Animal welfare	-	9.68	-		-	3	-	3
	Other	-	77.42	-		-	24	-	24
n				37	37			37	37
why do you not purchase meat?[4] (n=37)	Price	-	-	21.62	21.62	-	-	8	8
	Environmental	-	-	21.62	21.62	-	-	8	8
	Religious	-	-	2.70	2.70	-	-	1	1
	Ethical	-	-	21.62	21.62	-	-	8	8
	Animal welfare	-	-	16.22	16.22	-	-	6	6
	Other	-	-	78.37	78.37	-	-	29	29
Do you purchase any of the following alternative proteins/ meat	Tofu	-	-	21.6	21.6	-	-	8	8
	Impossible meats	-	-	13.5	13.5	-	-	5	5
	Beyond meats	-	-	13.5	13.5	-	-	5	5
	Other	-	-	75.7	75.7	-	-	28	28
	Veggie burger	-	-	24.3	24.3	-	-	9	9

substitutes?[4] (n=37)									
How often do you purchase beef[2] (n=970)	At least once a week	41.55	-	-	41.55	403	-	-	403
	At least once every two weeks	28.76	-	-	28.76	279	-	-	279
	At least once a month	20.93	-	-	20.93	203	-	-	203
	At least once every 2 months	3.92	-	-	3.92	38	-	-	38
	Less than once every two months	4.85	-	-	4.85	47	-	-	47
n		970			970	970			970
When purchasing beef what do you typically buy[2] (n=970)	Grass-fed	18.24	-	-	18.24	177	-	-	177
	Aged	12.78	-	-	12.78	124	-	-	124
	Traditional/conventional	80.62	-	-	80.62	782	-	-	782
	organic	7.32	-	-	7.32	71	-	-	71
	Locally sourced	36.39	-	-	36.39	353	-	-	353
When purchasing beef, what is typically the number one factor influencing your purchasing decision?[2] (n=970)	price	38.87	-	-	38.87	377	-	-	377
	Color	8.35	-	-	8.35	81	-	-	81
	USDA Grade (marbling)	33.61	-	-	33.61	326	-	-	326
	weight	3.81	-	-	3.81	37	-	-	37
	Number of steaks included in the package	2.27	-	-	2.27	22	-	-	22
	availability	7.22	-	-	7.22	70	-	-	70
	other	5.88	-	-	5.88	57	-	-	57
Please mark the number of times a week on average you consume beef at home[2] (n=970)	0	1.34	-	-	1.34	13	-	-	13
	1	14.54	-	-	14.54	141	-	-	141
	2	22.27	-	-	22.27	216	-	-	216
	3	25.88	-	-	25.88	251	-	-	251
	4	16.29	-	-	16.29	158	-	-	158
	5	9.18	-	-	9.18	89	-	-	89
	6	3.20	-	-	3.20	31	-	-	31
	7 or more	7.32	-	-	7.32	71	-	-	71
Please mark the number of times a week	0	9.48	-	-	9.48	92	-	-	92
	1	36.08	-	-	36.08	350	-	-	350
	2	25.77	-	-	25.77	250	-	-	250
	3	14.12	-	-	14.12	137	-	-	137

on average you consume beef at a restaurant [2] (n=970)	4	6.08	-	-	6.08	59	-	-	59
	5	4.02	-	-	4.02	39	-	-	39
	6	1.55	-	-	1.55	15	-	-	15
	7 or more	2.89	-	-	2.89	28	-	-	28

Table 11. Frequency of type of beef purchased by certain demographic characteristics

Question	Characteristic	Frequency of type of beef purchased by respondents				
		Grass fed (n=177)	Aged (n=124)	Locally Sourced (n=353)	Organic (n=71)	Traditional/Conventional (n=782)
Biological Sex	Female (n=626)	111	73	238	51	491
	Male (n=341)	65	51	114	20	289
	Prefer not to specify (n=3)	1	0	1	0	2
Age	18-20 years (n=68)	13	4	33	10	57
	21-25 years (n=298)	59	19	104	22	237
	26-35 years (n=206)	37	31	87	14	172
	36-45 years (n=111)	14	19	36	9	94
	46-55 years (n=109)	20	13	33	4	85
	56-65 years (n=105)	22	28	36	9	78
	66 years and older (n=73)	12	10	24	3	59
Household Income	Below $25,000 (n=148)	27	9	53	17	125
	$25,001 - 49,999 (n=123)	25	8	39	6	96
	$50,000 – 74,000 (n=167)	27	16	69	10	141
	$75,000 – 99,999 (n=178)	28	35	75	7	133
	$100,000 or more (n=354)	70	56	117	31	287
Highest degree earned	High school or equivalent (n=158)	31	17	63	18	128
	Trade school (n=38)	12	8	18	5	25
	2-year degree (n=91)	22	8	42	8	62
	4-year degree (n=415)	70	45	150	24	339
	Advanced degree (n=268)	42	46	80	16	228
Knowledge of the animal agriculture industry	Not knowledgeable (n=108)	32	7	21	21	74
	Slightly knowledgeable (n=146)	50	8	46	21	115

	Somewhat knowledgeable (n=226)	65	29	103	19	171
	Very knowledgeable (n=300)	26	42	121	10	247
	Extremely knowledgeable (n=190)	4	38	62	0	175
Knowledge of the meat industry	Not knowledgeable (n=120)	37	9	25	21	86
	Slightly knowledgeable (n=192)	65	10	74	25	142
	Somewhat knowledgeable (n=327)	53	39	137	16	264
	Very knowledgeable (n=234)	20	45	96	8	197
	Extremely knowledgeable (n=97)	2	21	21	1	93

Table 12. Frequency of characteristics that influence beef purchasing decisions by certain demographic characteristics

Question	Characteristic	Frequency of characteristics that influence beef purchasing decisions						
		Price (n=377)	Color (n=81)	USDA Grade (marbling) (n=326)	Weight (n=37)	Number of steaks included in the package (n=22)	Availability (n=70)	Other (n=57)
Biological Sex	Female (n=626)	248	55	188	30	13	49	43
	Male (n=341)	127	26	138	7	8	21	14
	Prefer not to specify (n=3)	2	0	0	0	1	0	0
Age	18-20 years (n=68)	33	4	19	4	2	3	3
	21-25 years (n=298)	131	30	81	9	13	21	13
	26-35 years (n=206)	82	18	72	4	3	19	8
	36-45 years (n=111)	41	7	36	8	0	7	12
	46-55 years (n=109)	43	9	41	4	2	5	5
	56-65 years (n=105)	24	6	49	4	1	8	13
	66 years and older (n=73)	23	7	28	4	1	7	3
Household Income	Below $25,000 (n=148)	79	13	32	5	5	7	7
	$25,001 - 49,999 (n=123)	60	11	29	2	5	11	5
	$50,000 – 74,000 (n=167)	78	13	42	7	3	14	10
	$75,000 – 99,999 (n=178)	66	14	67	2	2	12	15
	$100,000 or more (n=354)	94	30	156	21	7	26	20
Highest degree earned	High school or equivalent (n=158)	73	14	46	4	5	9	7
	Trade school (n=38)	13	4	14	1	1	1	4
	2-year degree (n=91)	43	8	31	4	0	3	2
	4-year degree (n=415)	153	30	144	14	11	39	24
	Advanced degree (n=268)	95	25	91	14	5	18	20

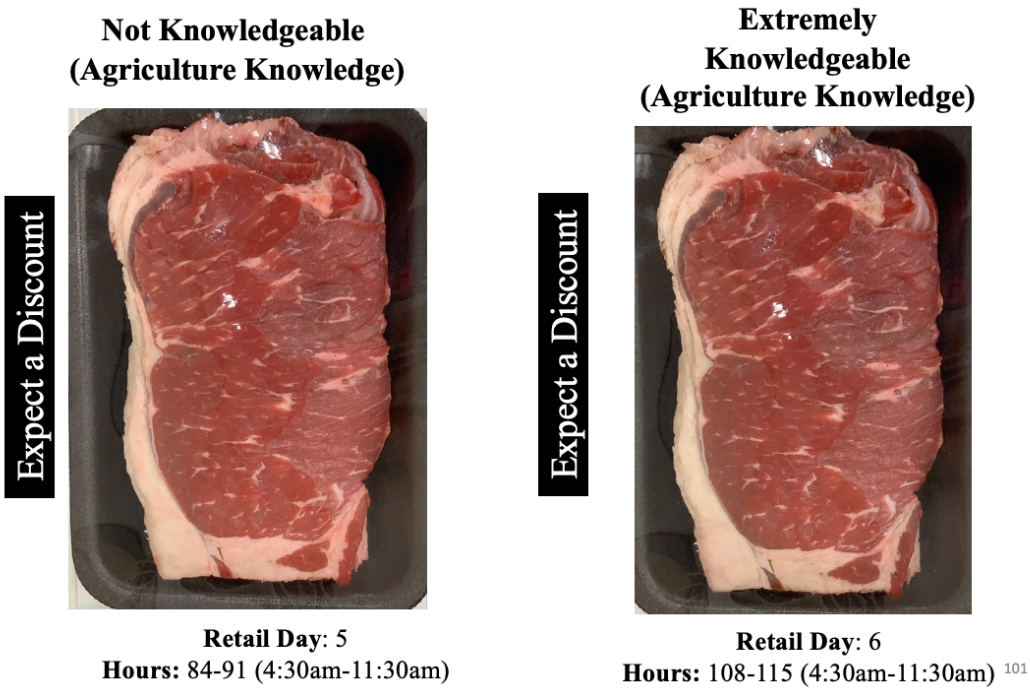
Knowledge of the animal agriculture industry	Not knowledgeable (n=108)	46	18	18	10	5	5	6
	Slightly knowledgeable (n=146)	71	12	28	10	4	11	10
	Somewhat knowledgeable (n=226)	98	26	55	10	3	21	13
	Very knowledgeable (n=300)	101	19	131	6	5	19	19
	Extremely knowledgeable (n=190)	61	6	94	1	5	14	9
Knowledge of the meat industry	Not knowledgeable (n=120)	55	17	16	10	4	9	9
	Slightly knowledgeable (n=192)	86	16	42	11	5	20	12
	Somewhat knowledgeable (n=327)	138	24	107	13	5	21	19
	Very knowledgeable (n=234)	70	17	112	3	6	13	13
	Extremely knowledgeable (n=97)	28	7	49	0	2	7	4

Table 13. Average Seconds respondents expected a discount or would stop purchasing the products displayed on video in the consumer preference survey by certain demographic characteristics

Question	Characteristic	Average seconds of the survey videos	
		Expect a Discount (s)	Stop Purchasing (s)
Biological Sex	Female (502)	13	16
	Male (284)	13	18
	Prefer not to specify (2)	11	17
Age	18-20 years (52)	12	16
	21-25 years (248)	12	16
	26-35 years (172)	13	17
	36-45 years (92)	13	17
	46-55 years (91)	13	17
	56-65 years (81)	12	17
	66 years and older (50)	13	17
Household Income	Below $25,000 (121)	13	16
	$25,001 - 49,999 (99)	12	17
	$50,000 – 74,000 (131)	12	16
	$75,000 – 99,999 (144)	12	17
	$100,000 or more (291)	13	17
Highest degree earned	High school or equivalent (125)	12	15
	Trade school (31)	13	18
	2-year degree (65)	13	16
	4-year degree (347)	13	17
	Advanced degree (218)	13	17
Knowledge of the animal agriculture industry	Not knowledgeable (86)	11	14
	Slightly knowledgeable (113)	12	16

	Somewhat knowledgeable (175)	12	16
	Very knowledgeable (245)	13	17
	Extremely knowledgeable (167)	14	18
Knowledge of the meat industry	Not knowledgeable (92)	11	14
	Slightly knowledgeable (153)	11	15
	Somewhat knowledgeable (252)	13	17
	Very knowledgeable (202)	13	18
	Extremely knowledgeable (87)	13	18

Figure 1. The average seconds those who were not knowledgeable about the meat industry would expect a discount for the product compared to the average seconds those who were extremely knowledgeable about the meat industry would expect a discount for the product



[101]

Figure 2. The average seconds those who were not knowledgeable about the meat industry would stop purchasing the product compared to the average seconds those who were extremely knowledgeable about the meat industry would stop purchasing the product

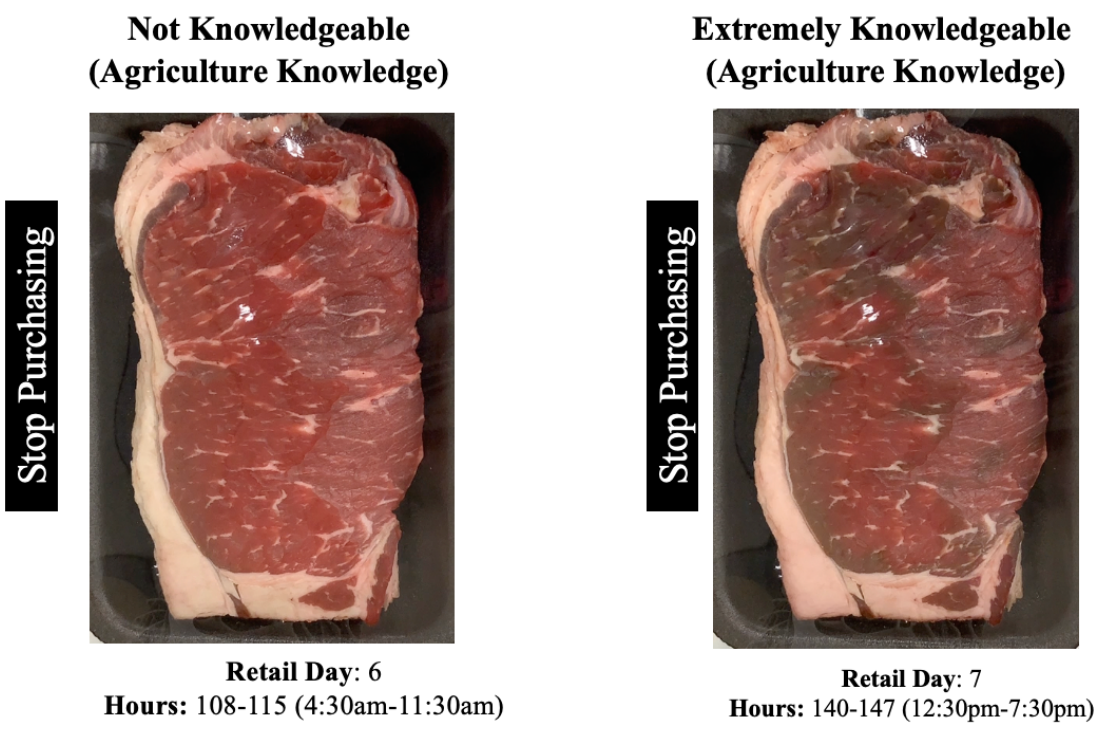


Figure 3. The average seconds those who were not or slightly knowledgeable about the meat industry would expect a discount for the product compared to the average seconds those who were somewhat, very, or extremely knowledgeable about the meat industry would expect a discount for the product

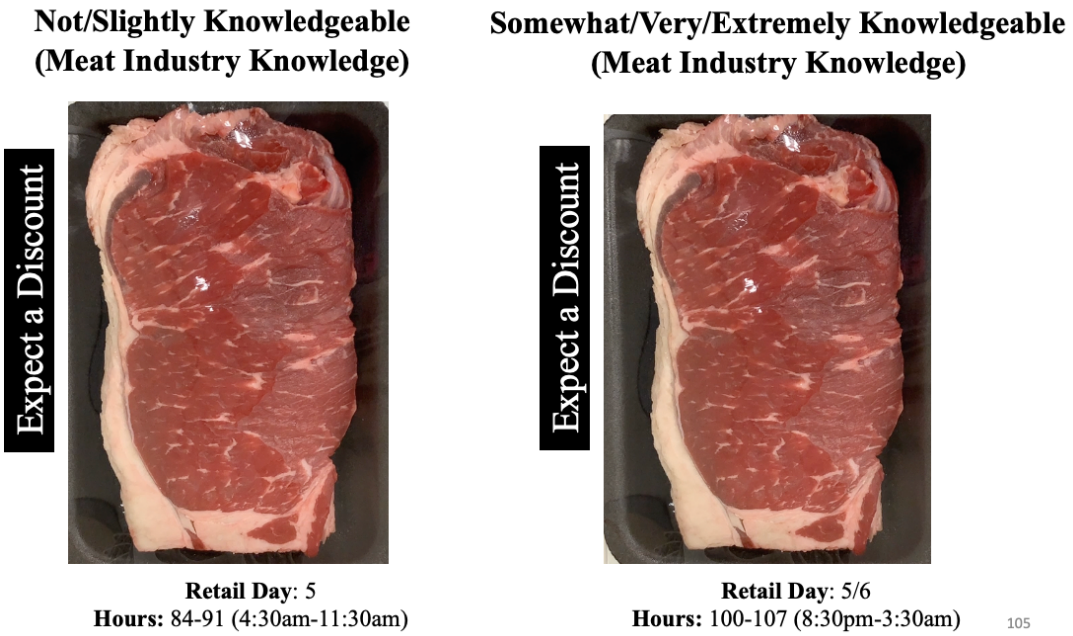


Figure 4. The average seconds those who were not knowledgeable about the meat industry would stop purchasing the product compared to the average seconds those who were very or extremely knowledgeable about the meat industry would stop purchasing the product.

Not Knowledgeable (Meat Industry Knowledge)

Retail Day: 6
Hours: 108-115 (4:30am-11:30am)

Very/Extremely Knowledgeable (Meat Industry Knowledge)

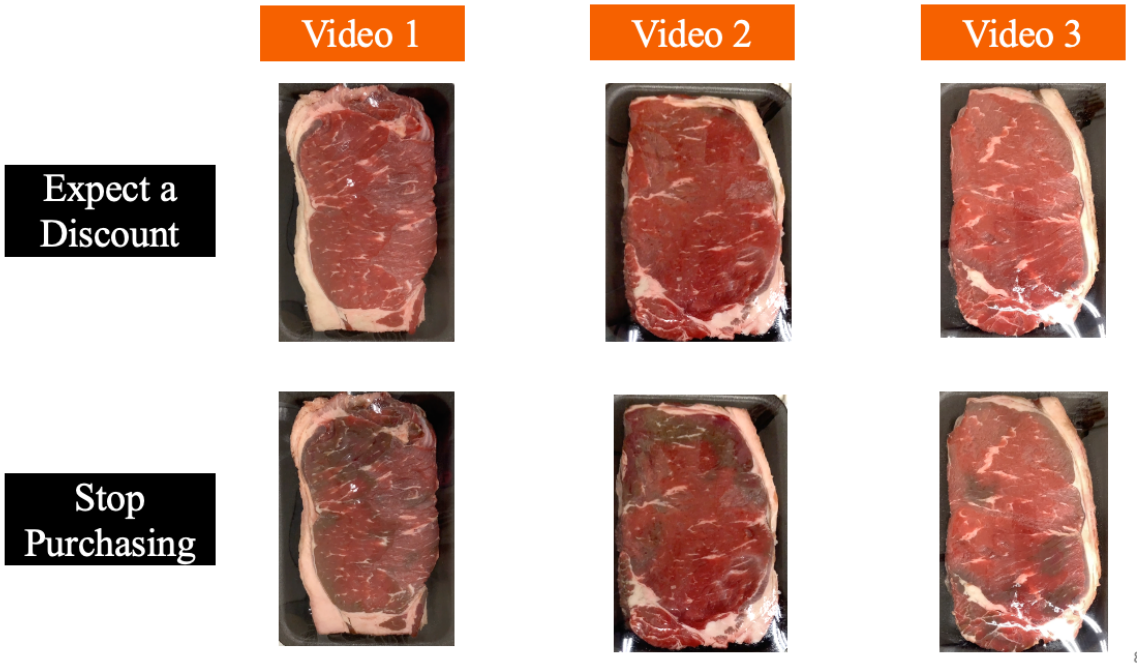
Retail Day: 7
Hours: 140-147 (12:30pm-7:30pm) [106]

Question was only displayed to respondents who purchase beef products

Table 14. Average Number of seconds respondents would expect a discount or stop purchasing for each video

Video Number	Average Seconds	
	Expect a discount	Stop purchasing
Video 1	13.87	18.24
Video 2	13.19	17.20
Video 3	12.11	15.83

Figure 5. Average Number of seconds respondents would expect a discount or stop purchasing for each video



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APPENDICES

APPENDIX A

Color Scoring Hedonic Scales		
Visual Color	Surface Discoloration	Overall Acceptability
1= Extremely Bright Cherry Red	1= No Discoloration (0%)	1= Very Definitely Would Not Purchase
2= Bright Cherry Red	2= Slight Discoloration (1-20%)	2= Definitely Would Not Purchase
3= Moderately Bright Cherry Red	3= Small Discoloration (21-40%)	3= Probably Would Not Purchase
4. Slightly Bright Cherry Red	4= Modest Discoloration (41-60%)	4= May or May Not Purchase
5. Slightly Dark Cherry Red	5= Moderate Discoloration (61-80%)	5= Probably Would Purchase
6. Moderately Dark Red	6= Extensive Discoloration (81-100%)	6= Definitely Would Purchase
7. Dark Red		7= Very Definitely Would Purchase
8. Extremely Dark Red		

APPENDIX B

Oklahoma State University Institutional Review Board

Date:	07/20/2022
Application Number:	IRB-22-286
Proposal Title:	Consumer Preference of Meat Color
Principal Investigator:	Morgan Pfeiffer
Co-Investigator(s):	
Faculty Adviser:	
Project Coordinator:	
Research Assistant(s):	Dani Gene LeDonne
Processed as:	Exempt
Exempt Category:	

Status Recommended by Reviewer(s): Approved

The IRB application referenced above has been approved. It is the judgment of the reviewers that the rights and welfare of individuals who may be asked to participate in this study will be respected, and that the research will be conducted in a manner consistent with the IRB requirements as outlined in 45CFR46.

This study meets criteria in the Revised Common Rule, as well as, one or more of the circumstances for which continuing review is not required. As Principal Investigator of this research, you will be required to submit a status report to the IRB triennially.

The final versions of any recruitment, consent and assent documents bearing the IRB approval stamp are available for download from IRBManager. These are the versions that must be used during the study.

As Principal Investigator, it is your responsibility to do the following:

1. Conduct this study exactly as it has been approved. Any modifications to the research protocol must be approved by the IRB. Protocol modifications requiring approval may include changes to the title, PI, adviser, other research personnel, funding status or sponsor, subject population composition or size, recruitment, inclusion/exclusion criteria, research site, research procedures and consent/assent process or forms.
2. Submit a request for continuation if the study extends beyond the approval period. This continuation must receive IRB review and approval before the research can continue.
3. Report any unanticipated and/or adverse events to the IRB Office promptly.
4. Notify the IRB office when your research project is complete or when you are no longer affiliated with Oklahoma State University.

Please note that approved protocols are subject to monitoring by the IRB and that the IRB office has the authority to inspect research records associated with this protocol at any time. If you have questions about the IRB procedures or need any assistance from the Board, please contact the IRB Office at 405-744-3377 or irb@okstate.edu.

Sincerely,
Oklahoma State University IRB

APPENDIX C

Consumer Preference of Meat Color Survey Consent Form

You are invited to participate in a brief research study, the purpose of which is to evaluate opinions and beliefs related to beef color and purchasing habits. Your participation is completely voluntary.
To be eligible to participate in this study, you must be age 18 years or older.

Study procedures:
Brief questions where you will select answers that represent your opinions and beliefs about beef color and purchasing habits. Total time commitment for study: approximately 15-25 minutes

Risks of Study Participation:
There are no foreseeable risks to you for taking this survey. This survey is anonymous, and data collected will not be tied back to you. All your answers are kept completely confidential and will not be shared with anyone. Data will only be accessible to and used by approved OSU researchers. We are not collecting any sensitive information. The only alternative to this study is not participating.

Benefits:
There are no direct benefits to you for participating, other than contributing to research.

Compensation:
You will receive no compensation for participating in this study.

Privacy:
The research team works to ensure confidentiality to the degree permitted by technology. It is possible, although unlikely, that unauthorized individuals could gain access to your responses because you are responding online. However, your participation in this online survey involves risks similar to a person's everyday use of the internet. If you have concerns, you should consult the survey provider privacy policy at Data Protection & Privacy (qualtrics.com

Contacts and Questions:

The Institutional Review Board (IRB) for the protection of human research participants at Oklahoma State University has reviewed and approved this study. If you have questions about the research study itself, please contact the Principal Investigator at (405) 744 9262 or morgan.pfeiffer@okstate.edu. If you have questions about your rights as a research volunteer or would like to speak with someone other than the research team about concerns regarding this study, please contact the IRB at (405) 744-3377 or irb@okstate.edu. All correspondence will be kept confidential.

To agree to participate in the study and advance to the survey, please select I Agree and press the next button.

INSTRUCTIONS

Thank you for your participation in this study. Your assistance is very much appreciated. The objective of this study is to determine preferred purchasing time. Please take your time and evaluate the videos carefully.

This questioner will take about 30 minutes. Please answer the following questions as completely as possible.

Please begin by filling out the basic demographic questions. This information is confidential and will not have your name associated with it in any way.

After completing the demographic information, you are ready to begin the video evaluation.

Instructions are provided at the top of each video and will give you guidance on how to evaluate each video.

Thank you very much for your help with this study.

DEMOGRAPHICS BALLOT

Please select the state you currently reside in

Please circle each appropriate response:

1. Please select which level best describes your knowledge of the animal agriculture industry
    - Not knowledgeable
    - Slightly knowledgeable
    - Somewhat knowledgeable
    - Very knowledgeable
    - Extremely knowledgeable

2. Please select which level best describes your knowledge of the meat industry

    - Not knowledgeable
    - Slightly knowledgeable
    - Somewhat knowledgeable
    - Very knowledgeable
    - Extremely knowledgeable

3. Please indicate your biological sex:

    - Male
    - Female
    - Prefer not to Specify

4. Which of the following best describes your age?

    - 20 years or younger
    - 21-25 years
    - 26-35 years
    - 36-45 years
    - 46-55 years
    - 56-65 years
    - 66 years and older

5. Please indicate your current working status:

    - Not employed
    - Student
    - Part-time
    - Full-time

6. Which of the following best describes your household income, pre-tax?
    - Below $25,000
    - $25,001 - 49,999
    - $50,000 - 74,999
    - $75,000 – 99,999
    - $100,000 or more

7. What is the highest degree or level of school you have completed?
    - High school or equivalent
    - Trade school
    - 2 year degree
    - 4 year degree
    - Advanced degree

8. Please indicate your ethnic background:
    - Caucasian
    - African American
    - Hispanic
    - American Indian
    - Asian or Pacific Islander
    - Other

9. Are you the primary shopper in your household?
    - Yes
    - No
    - I share equally in the food purchasing decisions
10. Do you purchase meat?
    - Yes
    - No

IF YES MOVE TO QUESTION 11
IF NO MOVE TO QUESTION 16

11. Which of the following meats do you purchase (please select all that you consume)?

- Chicken
- Beef
- Pork
- Lamb
- Fish or Seafood

IF THEY STATE THEY PURCHASED BEEF MOVE TO QUESTION 12
IF THEY STATE THEY DO NOT PURCHASE BEEF MOVE TO QUESTION 18

12. You said that you purchase beef. Approximately how often do you purchase beef?
    - At least once a week
    - At least once every 2 weeks
    - At least once a month
    - At least once every two months
    - Less than once every two months

13. When purchasing beef, what do you typically buy?
    - Grass-fed
    - Aged
    - Traditional/conventional
    - Organic
    - Locally Sourced

14. When purchasing beef, what is typically the number one factor influencing your purchasing decision?
    - Price
    - Color
    - USDA grade (marbling)
    - Weight
    - Number of steaks included in the package
    - Availability
    - Other

15. Please mark the number of times a week (all meals) you consume beef (including ground beef):

At Home:	0	1	2	3	4	5	6	7 or more
Restaurant or Fast-food Establishment:	0	1	2	3	4	5	6	7 or more

16. You said that you do not purchase meat. Which of the following reasons indicate why you do not purchase meat (please select all that apply)?
    - Price
    - Environmental reasons

- Religious reasons
- Ethical reasons
- Animal Welfare
- Other

17. Do you purchase any of the following alternative proteins/meat substitutes (please select all you purchase)?
    - Veggie burgers
    - Tofu
    - Impossible meats
    - Beyond meats
    - Other

18. You said that you do not purchase beef. Which of the following reasons indicate why you do not purchase beef (please select all that apply)?
    - Price
    - Environmental reasons
    - Religious reasons
    - Ethical reasons
    - Animal Welfare
    - Othe

APPENDIX D

Time-Lapse Video seconds conversion to retail days and hours				
Video seconds	Date	Retail Day	Time	Retail hours
0s=	3/25/22	1	4:30pm-7:30pm	0-3
1s=	3/25/22-3/26/22	1/2	8:30pm- 3:30am	4-11
2s=	3/26/22	2	4:30am-11:30am	12-19
3s =	3/26/22	2	12:30pm- 7:30pm	20-27
4s=	3/26/22-3/27/22	2/3	8:30pm- 3:30am	28-35
5s=	3/27/22	3	4:30am-11:30am	36-43
6s=	3/27/22	3	12:30pm-7:30pm	44-51
7s=	3/27/22-3/28/22	3/4	8:30pm-3:30am	52-59
8s=	3/28/22	4	4:30am-11:30am	60-67
9s =	3/28/22	4	12:30pm-7:30pm	68-75
10s=	3/28/22-3/29/22	4/5	8:30pm-3:30am	76-83
11s=	3/29/22	5	4:30am-11:30am	84-91
12s=	3/29/22	5	12:30pm-7:30pm	92-99
13s=	3/29/22-3/30/22	5/6	8:30pm-3:30am	100-107
14s=	3/30/22	6	4:30am-11:30am	108-115
15s=	3/30/22	6	12:30pm-7:30pm	116-123
16s=	3/30/22-3/31/22	6/7	8:30pm-3:30am	124-131
17s=	3/31/22	7	4:30am-11:30am	132-139
18s=	3/31/22	7	12:30pm-7:30pm	140-147
19s=	3/31/22-4/1/22	7/8	8:30pm-3:30am	148-155
20s=	4/1/22	8	4:30am-11:30am	156-163
21s=	4/1/22	8	12:30pm-7:30pm	164-171
22s=	4/1/22	8/9	8:30pm-3:30am	172-179
23s=	4/2/22	9	4:30am-11:30am	180-187
24s=	4/2/22	9	12:30pm-7:30pm	188-195
25s=	4/2/22 - 4/3/22	9/10	8:30pm-3:30am	196-203
26s=	4/3/22	10	4:30am-11:30am	204-211
27s=	4/3/22	10	12:30pm-7:30pm	212-219
28s=	4/3/22 - 4/4/22	10/11	8:30pm-3:30am	220-227
29s=	4/4/22	11	4:30am-11:30am	228-235
30s=	4/4/22	11	12:30pm-4:30pm	236-240

VITA

Dani Gene LeDonne

Candidate for the Degree of

Master of Science

Thesis: THE USE OF TIME-LAPSE VIDEO SURVEILLANCE TO EVALUATE MEAT COLOR

Major Field: Animal Science

Biographical:

Education:

Completed the requirements for the Master of Science in Animal Science at Oklahoma State University, Stillwater, Oklahoma in December, 2022.

Completed the requirements for the Bachelor of Science in Animal Science at Oklahoma State University, Stillwater, Oklahoma in 2021.

Experience:

Graduate Research and Teaching Assistant. Oklahoma State University, Department of Animal Science, Stillwater, OK.

Professional Memberships:

American Meat Science Association