Determining the Spoilage Threshold for Ground Beef Using Multiple Objective Measures

L.M. Frink, S.L. Witberler, M.J. Prester, E.S. Beyer, J.L. Vipham, M.D. Zumbaugh, M.D. Chao, and T.G. O'Quinn

Abstract

The objective of this study was to determine the point at which ground beef reaches spoilage as determined by consumers. Retail ground beef packages were procured from a case-ready ground beef facility and randomly assigned to a storage duration (0 – 14 days) for simulated retail display. Packages were stored in mother bags at 36 – 40°F in the absence of light until placed in the retail case under fluorescent lights on the designated display date. Samples were displayed in three coffin-style cases at 36 – 40°F for 8 different display periods (0, 2, 4, 6, 8, 10, 12, and 14 days). Consumer sensory panelists evaluated eight samples for visual appearance, odor, and touch. For each measure, consumers were asked if they would purchase the sample and if they considered the sample spoiled. Trained sensory panelists evaluated the same samples on the same day of display and were asked to evaluate redness, percent discoloration, odor, and touch characteristics. Consumers were less ($P < 0.05$) likely to purchase and more ($P < 0.05$) likely to rate samples spoiled once samples reached 8 days of display for visual appearance, touch, and odor. Consumer evaluation of the visual appearance score of the samples showed the strongest relationship to spoilage, having a high R^2 of 0.89 ($P < 0.05$). Threshold values of 50%, 75%, 90%, and 95% were identified for consumer purchase intent likelihood using multiple objective measures. With an R^2 of 0.86 ($P < 0.05$), trained panel redness scores of 60.15, 73.9, 87.6, and 96.95 corresponded to 50%, 75%, 90%, and 95% likelihood of a consumer purchasing the product. The likelihood of consumers classifying a sample as spoiled ($R^2 = 0.76$) 5, 10, 25, and 50% of the time corresponded with a trained sensory panel redness score of 74.8, 64.1, 48.4, and 32.7, respectively. Overall, consumers' opinion towards the appearance of the product plays the biggest role in their purchase intent and assessment of spoilage as opposed to touch and odor.

Introduction

The global population is projected to increase by approximately 10% by the year 2031 (Dohlman et al., 2022). With this impending increase, safeguarding food products within the supply chain has a heightened significance. An overwhelming 23% of the world's produced meat goes to waste, with spoilage standing out as a primary culprit (Karwowska et al., 2021). Food waste is responsible for an annual cost of 780,000 animals in the beef industry alone, coupled with financial losses exceeding $3.73 billion due to discoloration (Ramanathan, 2022). Notably, much of the meat removed from shelves remains consumable, falling short only of consumer preferences. Consequently, a significant portion of beef product is prematurely withdrawn from retail shelves before reaching its full shelf-life potential. By recognizing that consumers are deterred by the oxidized metmyoglobin brown color replacing the bright cherry-red color of fresh meat, it's essential to revisit the benchmarks of spoilage (Harr, 2021). Therefore, the purpose of this study was to establish spoilage thresholds for ground beef using multiple measures to offer the meat industry valuable insights for better product management, ultimately increasing the shelf-life of ground beef by aligning with the consumer's expectations of freshness and quality.

Experimental Procedures

This study utilized 1-pound ground beef (80% lean) packages obtained from a commercial case-ready ground beef facility. Packages were stored at 36 – 40°F in gas-flushed mother bags in the absence of light at the Kansas State University Meat Laboratory. Four individual packages were stored in one mother bag (Tri gas, 69.6% nitrogen, 30% carbon dioxide, 0.4% carbon monoxide). Packages within a mother bag (2 pair per mother bag) were randomly assigned a display day (0, 2, 4, 6, 8, 10, 12, and 14 days). One paired sample was assigned to color and visual analysis while the other paired sample was utilized for smell and touch sensory analysis. Samples were placed in three coffin-style cases (model DMF8; Tyler Refrigeration Corp., Niles, MI) at 36 – 40°F under continuous fluorescent lighting (32 W Del-Warm White 3,000 K; Phillips Lighting Company, Somerset, NJ) for the duration of their assigned display period. Samples (n = 128) were placed in the case every other day from 14 days prior to evaluation until day 0 samples were displayed. Samples were placed in the case at the same time every day and rotated daily. To avoid fogging of packages during evaluation, the display cases were set to defrost once per day in the morning, prior to new samples being added. Each display case was divided into three sections (A - I) with distinct barriers. In addition to consumer sensory panels, objective measurements such as trained sensory panels, L^* (lightness), a^*(redness), and b^* (yellowness) readings using a Hunter Lab Miniscan spectrophotometer (Illuminant A, 2.54 cm aperture, 10° observer, Hunter Lab Associates Laboratory, Reston, VA), and spectral data were collected to calculate percent myoglobin present using the methods outlined in the American Meat Science Association (AMSA) color guidelines (AMSA, 2012).

Consumer sensory panelists (n = 128) were asked to evaluate one section of the display case that included 8 samples (one from each display period) and rate the visual appearance. Additionally, consumers were asked to evaluate the touch and odor of the samples under low-intensity red lights to avoid any bias toward the color of the product. For all attributes the consumers rated their overall liking of the sample on continuous 0 – 100-point line scales. They were also asked if they would purchase the sample (yes/no) or consider it spoiled (yes/no) based upon the attribute they were observing.

Trained sensory panelists also evaluated the samples for visual appearance, touch, and odor. During the weeks leading up to trained panels, panelists were trained with numerous samples of varying characteristics anchored to the scales. For color evaluation, panelists were trained according to the AMSA meat color measurement guidelines (AMSA, 2012). Panelists were asked to evaluate discoloration and redness of the samples using 100-point continuous line scales with anchors at 0 (0% discoloration and extremely dark red) and 100 (100% discoloration and bright, cherry-red color). Furthermore, panelists evaluated the texture of the samples by touch using a continuous

100-point line scale with anchors at 0 (characteristic beef texture) and 100 (non-characteristic beef texture). The odor of the samples was also evaluated on a continuous 100-point line scale with anchors at 0 (no odor present) and 100 (extreme off odor present). Trained panelists evaluated both touch and odor under the same red lights as consumers to avoid any bias toward the sample color. Both trained and consumer panelists recorded their answers using electronic tablets (Model 5709 HP Stream 7, Hewlett – Packard, Palo Alto, CA) utilizing a digital survey (Qualtrics Software, Provo, UT). Data were analyzed using logistic regression models to identify the points at which consumers determined a product to be spoiled based on visual, touch, and odor characteristics.

Results and Discussion

Overall, consumers rated samples that had been in the case for less time higher ($P < 0.05$) for visual appearance, touch, and odor liking. Consumer likeliness to purchase thresholds for visual appearance were generated from logistic regression equations and common threshold values of (50%, 75%, 90%, and 95% likely) that were identified using the values of independent variables measured represented in Table 1. Consumer visual appearance scores explained 89% of the variation of consumer purchase intent. A model with an R^2 of 0.79 ($P < 0.05$) for a^* values of 21.5, 24.8, 28, and 30.2, corresponded to 50%, 75%, 90%, and 95% likelihood of consumers purchasing the product as shown in Figure 1. Logistic models of consumer likeliness to purchase based on percent metmyoglobin present were also calculated ($R^2 = 0.81$; $P < 0.05$) with values of 37.5, 30.8, 24.35, and 19.95% associated with 50%, 75%, 90%, and 95% likelihood of consumer purchasing intent as shown in Figure 2. Additionally, as shown in Figure 3, consumer purchasing thresholds were generated from trained discoloration scores ($R^2 = 0.83$; $P < 0.05$) identifying 38.7%, 23.0%, and 7.3% discoloration associated with 50%, 75%, and 90% likelihood of purchase intent. Trained redness score models ($R^2 = 0.86$; $P < 0.05$) showed values of 60.2, 73.9, 87.6, and 97 corresponded to 50%, 75%, 90%, and 95% likelihood of purchase intent. Furthermore, logistic regression equations were used to identify at what point consumers determined the product to be spoiled, shown in Table 2. The equation ($R^2 = 0.80$; $P < 0.05$) for a^* identified values of 30.1, 27.2, 22.8, and 18.4 corresponding with a 5%, 10%, 25%, and 50% chance that a consumer would classify the sample as spoiled. For the percent metmyoglobin present ($R^2 = 0.72$; $P < 0.05$), values of 20.6%, 26.8%, 36%, and 45.1% were associated with a 5%, 10%, 25%, and 50% likelihood of being classified as spoiled. Consumer spoilage classification was also predicted with trained sensory panel discoloration and redness scores. Both trained redness and discoloration scores generated significant models representing about 75% of the variation of consumer spoilage classification.

Significant ($P < 0.05$) logistic regression models were also generated for odor liking to predict consumer likeliness to purchase thresholds but only described less than 8% of the variation within the model. Trained touch score logistic models for predicting spoilage classification were significant ($P < 0.05$) but only explained 3% of the variation. Overall, measures related to the visual characteristics were much better predictors of consumer likelihood to purchase and identification of spoilage than measures related to changes in odor and touch characteristics.

Implications

Though many changes were identified throughout the retail display period, the change in color from a bright, cherry-red to brown was shown to be the most important factor considered by consumers when they identified whether or not samples were spoiled; therefore, maintaining beef in a bright, cherry-red state is crucial to maximize value.

References

Dohlman, E., J. Hansen, and D. Boussios. 2022. USDA agricultural projections to 2031. USDA Office of the Chief Economist Long-Term Projections Report OCE-2022-1. 10.22004/ag.econ.323859

AMSA. 2012. Meat color measurement guidelines. 2 ed. American Meat Science Association, Champaign, IL.

Harr, K. M. 2021. Impact of providing information about the fat content, primal source, price, and labeling terms on consumer sensory evaluation of ground beef from the same source. Master's Thesis, Kansas State University. *https://krex.k-state.edu/dspace/handle/2097/41700*

Karwowska, M., S. Łaba, and K. Szczepański. 2021. Food loss and waste in meat sector—Why the consumption stage generates the most losses? Sustainability 13(11):6227. doi:10.3390/su13116227.

Ramanathan, R., L.H. Lambert, N. N. Mahesh, B. Morgan, R. Feuz, G. Mafi, and M. Pfeiffer. 2022. Economic loss, amount of beef discarded, natural resources wastage, and environmental impact due to beef discoloration. Meat and Muscle Biology 6(1):13218. doi:10.22175/mmb.13218

Table 1. 50, 75, 90, and 95% likeliness thresholds for various quality measures for consumer purchase intent of 80% lean ground beef

Measurement	50%	75%	90%	95%
*L**	54.4	55.9		
*a**	21.5	24.7	28.0	30.2
*b**	20.7	22.3	23.8	24.9
Metmyoglobin[1]	37.3	30.8	24.4	19.0
Oxymyoglobin[1]	59.5	65.7	71.8	75.9
TBARS[2]	0.3			
Trained sensory redness score[3]	60.2	73.9	87.6	96.0
Trained sensory discoloration score[4]	38.7	23.0	7.3	
Trained odor score[5]	22.5			
Trained touch score[6]	51.6	15.0		
Consumer appearance score[7]	48.5	59.5	70.5	77.0
Consumer odor score[7]	45.6	61.3	77.0	87.7
Consumer touch score[7]	43.15	56.9	70.6	80.0

[1]Calculated utilizing the equations presented in the AMSA Meat Color Measurement Guidelines (AMSA, 2012).
[2]Thiobarbituric acid reactive substances.
[3]Sensory scores: 0 = extremely dark red, 100 = bright cherry-red.
[4]Sensory Scored: 0 = no visible discoloration, 100 = complete discoloration.
[5]Sensory scores: 0 = no off odor, 100 = extreme off odor.
[6]Sensory scores: 0 = characteristic beef texture, 100 = non-characteristic beef texture.
[7]Sensory scores: 0 = extremely dislike, 100 = extremely like.

Table 2. 5, 10, 25 and 50% likeliness thresholds for various quality measures for consumer spoilage classification of 80% lean ground beef

Measurement	5%	10%	25%	50%
*L**			55.4	53.2
*a**	30.1	27.2	22.3	18.4
*b**	24.9	23.9	21.6	19.6
Metmyoglobin[1]	20.6	26.8	36.0	45.1
Oxymyoglobin[1]	77.0	71.5	62.3	53.2
TBARS[2]				0.5
Trained sensory redness score[3]	74.8	64.1	48.4	32.7
Trained sensory discoloration score[4]	1.6	16.5	38.5	60.4
Trained odor score[5]			9.6	64.5
Trained touch score[6]			34.1	
Consumer appearance score[7]	74.7	65.3	51.6	37.9
Consumer odor score[7]	79.1	68.4	52.7	37.0
Consumer touch score[7]	84.6	72.1	53.8	35.5

[1]Calculated utilizing the equations presented in the AMSA Meat Color Measurement Guidelines (AMSA, 2012).
[2]Thiobarbituric acid reactive substances.
[3]Sensory scores: 0 = extremely dark red, 100 = bright cherry-red.
[4] Sensory scores: 0 = no visible discoloration, 100 = complete discoloration.
[5] Sensory scores: 0 = no off odor, 100 = extreme off odor.
[6] Sensory scores: 0 = characteristic beef texture, 100 = non-characteristic beef texture.
[7] Sensory scores: 0 = extremely dislike, 100 = extremely like.

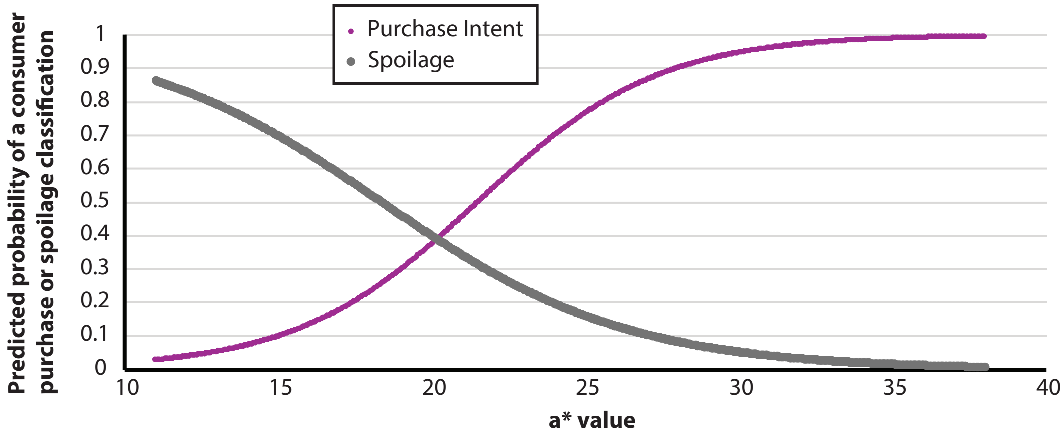

Figure 1. Threshold values for consumer likeliness to purchase 80% lean ground beef or classifying as spoiled according to a* value.

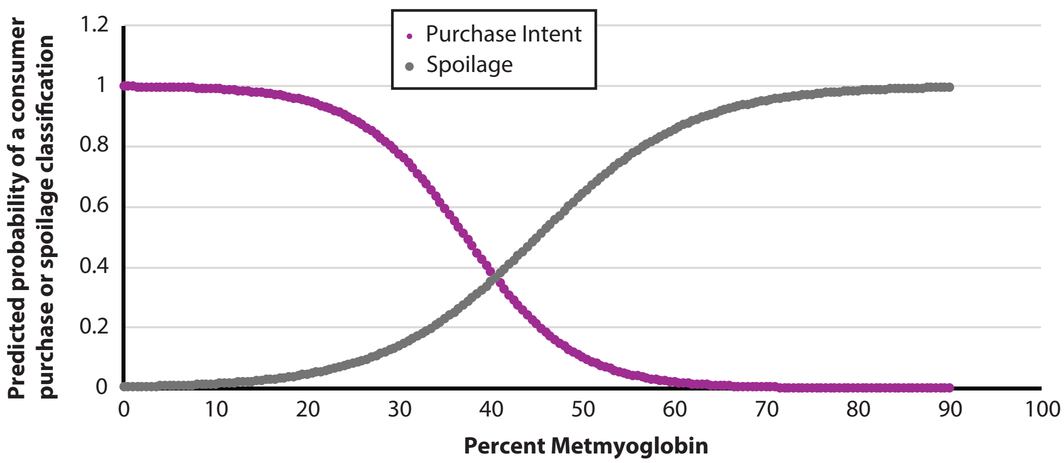

Figure 2. Threshold values for consumer likeliness to purchase 80% lean ground beef or classifying as spoiled according to metmyoglobin percentage.

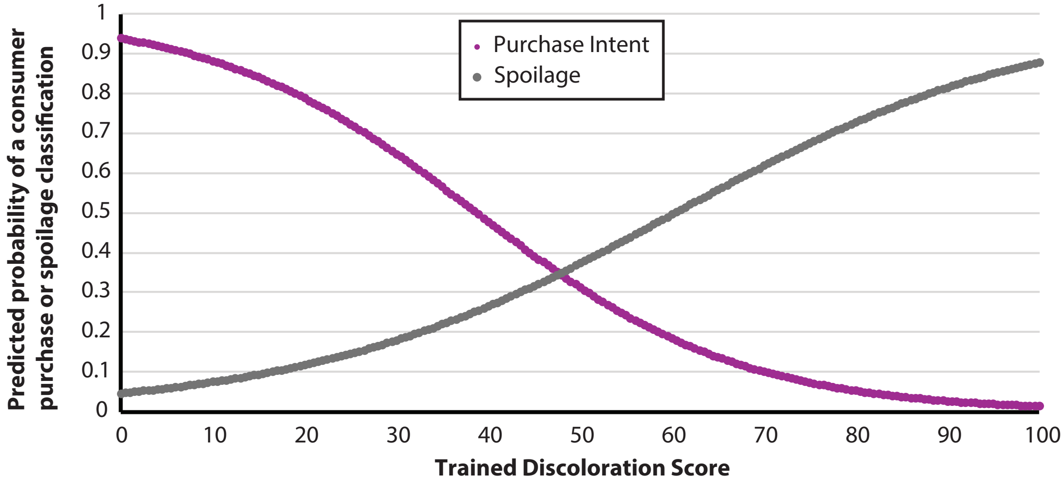

Figure 3. Threshold values for consumer likeliness to purchase 80% lean ground beef or classifying as spoiled according to trained discoloration scores where 0 = no visible discoloration, 100= complete discoloration.