The Cold Chain Question: Effects of Fresh, Frozen, and Thawed Beef Trim on Ground Beef Color and Consumer Perception

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Abstract

Ground beef is the most widely consumed beef product in the United States, with consumer purchasing decisions heavily influenced by visual appearance. Increasing reliance on imported lean trim, often shipped frozen, raises questions about how cold chain management affects ground beef quality. This study evaluated the effects of fresh, frozen, and thawed beef trim (50%, 80%, 90% lean) ground into 80% lean patties on ground beef color, lipid oxidation, and consumer perception. Consumer visual panelists assessed the appearance desirability and purchase intent, while the instrumental measures included lipid oxidation (Thiobarbituric Acid Reactive Substances; TBARS), CIE L^* (lightness) and a^* (redness) color values, and oxymyoglobin (bright cherry-red color) percentage. Patties containing fresh trim or fresh trim combined with frozen/thawed trim were rated highest ($P < 0.05$) for appearance and purchase intent, whereas exclusively frozen treatments were least preferred ($P < 0.05$). Lipid oxidation was greatest ($P < 0.05$) in frozen treatments and lowest ($P < 0.05$) in all-fresh trim, with instrumental color results supporting these trends. These findings demonstrate that the use of frozen lean trim negatively affects ground beef color and consumer acceptance, highlighting the importance of cold chain management strategies in maintaining product quality.

Introduction

Ground beef is a versatile, affordable staple for consumers, making it the most widely consumed beef product in the United States. Maintaining its color stability and extending shelf life are therefore vital for consumer satisfaction and industry profitability. Ground beef is produced from a balance of lean and fat trimmings (90%, 50%), but recent shifts in cattle markets have made maintaining that balance increasingly more difficult. In 2025, reduced beef and dairy cow harvest decreased domestic lean trim supplies, while heavier fed cattle added more fat but little lean (USDA Agricultural Marketing Service, 2025a, 2025b). This imbalance in the United States domestic market has led to a reliance on the importation of lean trim from international markets such as Australia, Brazil, and New Zealand (USDA Agricultural Marketing Service, 2025b). Imported trim is often shipped frozen, which supports supply consistency but may alter product quality (Rehman et al., 2024). These factors can directly influence meat color, an important driver of consumer purchase intent (Lybarger et al., 2023). Little research has been conducted focusing on the cold chain management strategies of beef trim, specifically, how fresh, frozen, and thawed materials affect consumer-perceived quality and objective measures of quality. Therefore, the objective of this study was to evaluate the impact of varying combinations of fresh, frozen, and thawed beef trim on the resulting quality characteristics of ground beef.

Experimental Procedures

Boxes of beef trim of various (50%, 80%, 90%) lean percentages were procured from a commercial processing facility and brought to the Kansas State University Meat Laboratory under refrigeration (36 – 39°F). Boxes were either held fresh at 36 – 39°F, frozen at -4°F, or thawed in the absence of light from a previously frozen state at 36 – 39°F for eight days. An equal number of boxes representing each lean percentage were assigned to a cold chain treatment. Using these raw materials, the following treatments were created: frozen 50%: frozen 90% (FZ50FZ90), frozen 50%: fresh 90% (FZ50FR90), fresh 50%: frozen 90% (FR50FZ90), frozen 80% (FZ80), fresh 50%: thawed 90% (FR50TH90), thawed 50%: fresh 90% (TH50FR90), thawed 50%: thawed 90% (TH50TH90), fresh 50%: fresh 90% (FR50FR90), fresh 80% (FR80), and thawed 80% (TH80).

For treatments containing trim of two combined lean points, 15 lb of 50% lean and 60 lb of 90% lean were weighed using a platform scale (Model BBA236; Mettler Toledo, Columbus, OH) to reach the desired lean point (80% lean). Trim was first coarse ground through a 3/8-in. plate using a grinder (Model #3344; Hobart, Troy, OH), then transferred to a mixer-grinder (Model # 4246; Hobart, Troy, OH). When applicable, lean points were combined and mixed for 2 minutes, and then fine ground through a 1/8-in. plate. Approximately 10 lb of product collected sequentially from the grinder represented one batch (n = 4 batches per processing day). Each batch was formed into 1/3 lb patties, with the final 5 patties being selected for evaluation. The first package (three patties) was assigned to lab analyses. The second package (two patties) was designated for shelf-life evaluations, including consumer visual panels and objective color measurements. Due to time and labor constraints, the patty fabrication process was repeated the following day to produce a total of 8 batches per treatment. All packages were placed randomly into coffin-style cases (Model DMF8; Tyler Refrigeration Corp., Niles, MI) at 36 – 39°F under fluorescent lights (32 W Del-Warm White 3,000 K; Philips Lighting Company, Somerset, NJ).

For all sensory evaluations, panelists recorded responses on electronic tablets (Fire HD 8; Amazon, Seattle, WA) using a digital survey (Qualtrics, Provo, UT). Consumer visual panels were conducted on packages designated for shelf-life evaluation on day 3 of retail display. Each consumer (n = 64) visually evaluated one package per treatment, presented in random order within a retail display case, using a 100-point continuous line scale for overall appearance desirability (Lybarger et al., 2023). Afterward, consumers indicated purchase intent (yes/no). If the response was "No," they were asked whether they would purchase the package at a discounted price (yes/no). Objective measurements such as lipid oxidation, CIE L^* (lightness) and a^* (redness), and spectral data were also collected each day of display. Lipid oxidation was measured using the Thiobarbituric Acid Reactive Substances (TBARS) assay as outlined by Ahn et al. (1998) on packages designated for lab assays after 0 + 3 days of display. Color data were collected using a Hunter Lab Miniscan spectrophotometer (Illuminant A, 1-in aperture, 10° observer; Hunter Lab Associates Laboratory, Reston, VA) to calculate the percent oxymyoglobin (bright cherry-red color) present using the methods outlined in King et al. (2023).

Results and Discussion

Results from consumer evaluations, found in Table 1, showed FZ50FR90, FR50FR90, and FR80 samples were rated the highest ($P < 0.05$) by consumers for appearance liking and had the greatest ($P < 0.05$) percentage of consumers who would purchase the samples at retail. Samples produced from only thawed trim were rated lower ($P < 0.05$) than samples made from thawed trim combined with fresh trim. However, these treatments still rated higher ($P < 0.05$) for appearance liking than FR50FZ90, which was also rated higher ($P < 0.05$) than FZ50FZ90 and FZ80. The percentage of consumers who would purchase at retail price followed a similar trend. Treatments from all fresh trim and fresh lean trim with frozen fat trim were the highest ($P < 0.05$), followed by thawed trim treatments. Within the samples made from thawed trim, TH50FR90 and FR50TH90 had a higher ($P < 0.05$) percentage of consumers willing to purchase at retail than TH50TH90. Samples from frozen lean and fresh fat trim (FR50FZ90) were more likely to be purchased at retail ($P < 0.05$) than samples derived from only frozen trim (FZ50FZ90), with FZ80 samples being similar ($P > 0.05$) to both combinations. These findings indicate consumers preferred treatments derived from fresh or thawed trim to frozen trim. As expected, TBARS values, shown in Table 1, showed an inverse trend to consumer preferences. For frozen trim, oxidation was greatest ($P < 0.05$) in FZ80, followed by FZ50FZ90, which exceeded the oxidation of FR50FZ90 ($P < 0.05$). The TH80 treatment was higher ($P < 0.05$) than TH50FR90, with FR50TH90 being similar to both ($P > 0.05$). The lowest oxidation occurred in FR50FR90, which was only similar to TH50TH90. These results align with consumer data, as treatments combining frozen lean showed greater oxidation and reduced purchase intent.

Over the entire retail display period, FZ80 samples had the highest ($P < 0.05$) L^* values, being the lightest in color (Figure 1). On days 0, 2, 3, 4, and 5, FZ50FZ90 and FR50FZ90 were brighter ($P < 0.05$) than all other treatments except FZ80 throughout display. In contrast, TH50TH90 samples had the lowest ($P < 0.05$) L^* values from day 2 through the end of display, indicating these samples were the darkest. All treatments containing thawed trim showed an increase ($P < 0.05$) in a^* values (Figure 2) on days 4 and 5, a trend consistent with the percentage of oxymyoglobin (Figure 3). Lybarger et al. (2023) found a^* and oxymyoglobin to be highly correlated to consumer purchase intent, which aligns with the present work as FR50FR90, FR80, and FZ50FR90 had the highest ($P < 0.05$) a^* values and percentage of oxymyoglobin on the day of consumer evaluation, which showed these treatments to have the greatest consumer appearance liking and purchase intent.

Implications

These results suggest grinding trim from a frozen state rather than incorporating fresh or thawed trim reduces consumer purchase intent, increases oxidation, and leads to reduced color stability, emphasizing the risks of frozen trim in ground beef quality.

Acknowledgments

Research coordinated by the National Cattlemen's Beef Association, a contractor to the Beef Checkoff.

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Table 1. Least-squares means for consumer appearance liking, percentage of consumers who would purchase at a retail or discounted price, and Thiobarbituric Acid Reactive Substances (TBARS) on day 3 of retail display

Treatment[1]	Appearance liking[3]	% Retail[4]	% Discounted[5]	TBARS[6]
FZ50FZ90	17.78^{e}	3.1^{f}	14.5^{cd}	2.71^{b}
FZ50FR90	81.69^{a}	93.8^{a}	75.0^{ab}	0.68^{e}
FR50FZ90	29.85^{d}	14.1^{e}	23.6^{bcd}	2.26^{c}
FZ80	14.35^{e}	4.7^{ef}	4.9^{d}	3.06^{a}
FR50TH90	59.77^{b}	56.3^{bc}	46.4^{abc}	0.78^{de}
TH50FR90	62.94^{b}	67.2^{b}	76.2^{a}	0.67^{e}
TH50TH90	42.67^{c}	32.8^{d}	39.5^{abc}	0.55^{ef}
FR50FR90	85.66^{a}	95.3^{a}	33.3^{abcd}	0.40^{f}
FR80	84.82^{a}	95.3^{a}	66.7^{abc}	0.65^{e}
TH80	47.81^{c}	45.3^{cd}	40.0^{abc}	1.00^{d}
SEM[2]	5.72	6.2	27.2	0.12
P - value	< 0.01	< 0.01	< 0.01	<0.01

[a-f]Least-squares means within the same column without a common superscript differ ($P < 0.05$).
[1]FZ50FZ90 = frozen 50%: frozen 90%; FZ50FR90 = frozen 50%: fresh 90%; FR50FZ90 = fresh 50%: frozen 90%; FZ80 = frozen 80%; FR50TH90 = fresh 50%: thawed 90%; TH50FR90 = thawed 50%: fresh 90%; TH50TH90 = thawed 50%: thawed 90%; FR50FR90 = fresh 50%: fresh 90%; FR80 = fresh 80%; and TH80 = thawed 80%.
[2]Standard error (largest) of least-squares means. SEM = standard error of the mean.
[3]Sensory scores: 0 = extremely dislike; 100 = extremely like.
[4]Percentage of consumers who would purchase at retail price.
[5]Percentage of the consumers who would not purchase at retail price but would purchase at a discounted price.
[6]TBARS values reported as mg MDA/kg.

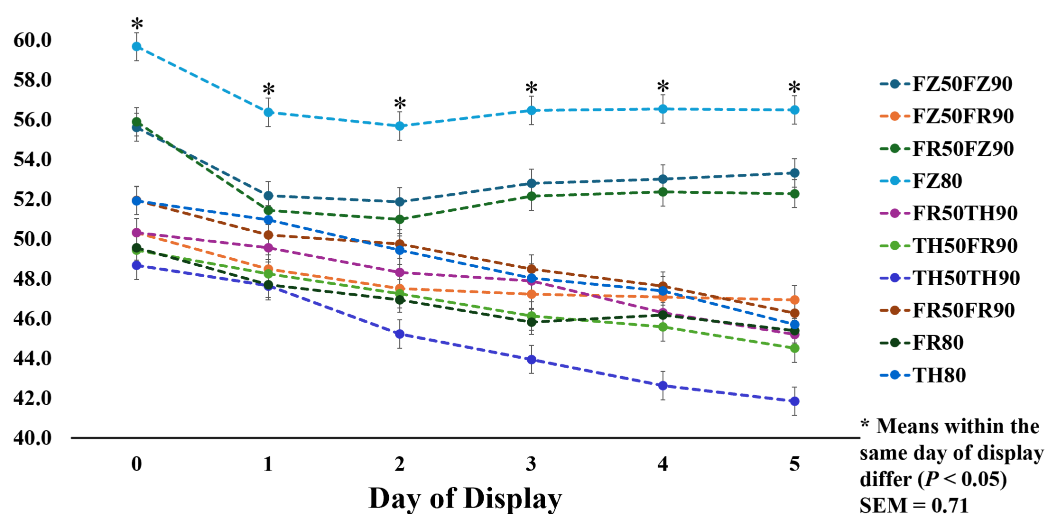

Figure 1. ***L** values by treatment across a retail display period**

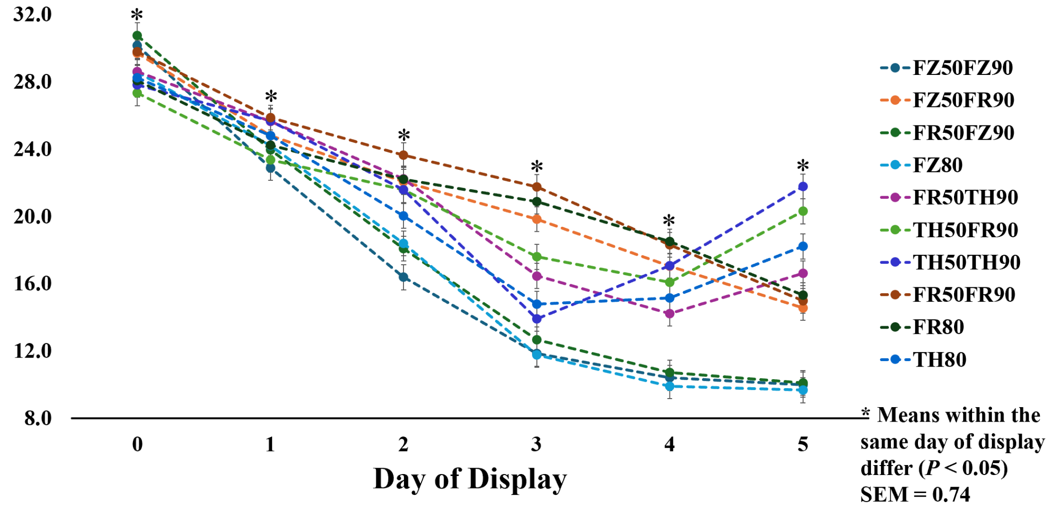

Figure 2. ***a**** **values by treatment across a retail display period**

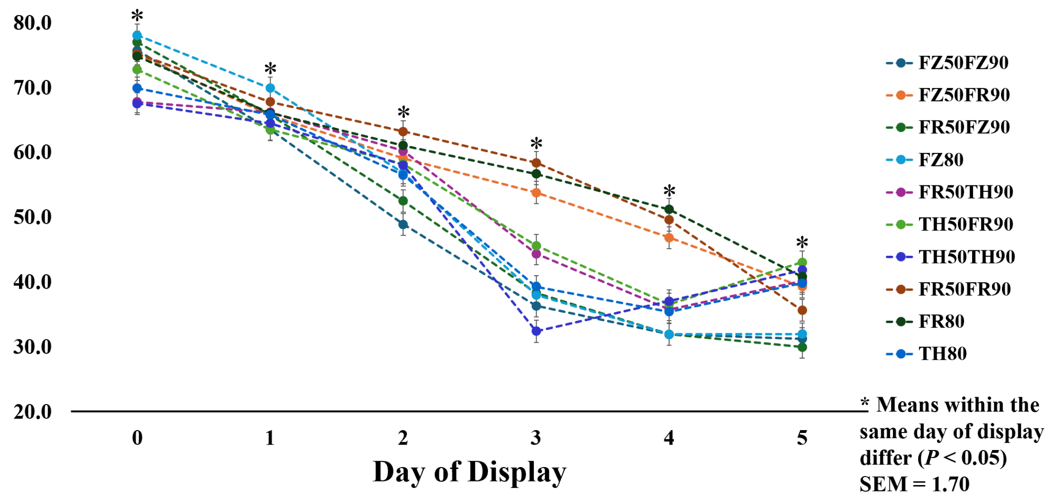

Figure 3. Percentage of oxymyoglobin by treatment across a period of retail display.