Effects of zilpaterol hydrochloride feeding duration on beef and calf-fed Holstein strip loin steak color

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ABSTRACT: Two studies using beef and calf-fed Holstein cattle were conducted to determine the effect of zilpaterol hydrochloride (ZH) supplementation on the color of strip loin steaks packaged in traditional and modified-atmosphere packaging. Select (USDA) strip loins were obtained from the carcasses of beef (n = 118) or calf-fed Holstein (n = 132) cattle fed ZH (6.8 g/ton on a 90% DM basis) for the last 0, 20, 30, or 40 d of feeding. One portion of the strip loin was moisture enhanced, cut into steaks, and packaged in an atmosphere containing 80% oxygen and 20% carbon dioxide. The remaining portion of the strip loin was vacuum-packaged until further processing. At 14 d postmortem, the vacuum-packaged loins were portioned and packaged in traditional retail packaging. Traditionally packaged and modified-atmosphere-packaged steaks were then placed in retail cases at −1 to 3°C for 5 d and evaluated by both trained and consumer panelists. Instrumental color values and purge loss were also recorded. Zilpaterol hydrochloride duration had no effect on the color and purchase intention scores of consumer panelists for beef and calf-fed Holstein strip loin steaks. Zilpaterol hydrochloride feeding duration had no effect on the color or discoloration scores of trained panelists for enhanced, modified-atmosphere-packaged beef strip steaks. Traditionally packaged beef steaks from cattle treated with ZH for 20 d had more desirable ($P < 0.05$) lean color scores than steaks from cattle not treated with ZH on d 2, 3, and 4 of display and had similar discoloration scores on d 1, 2, and 3 of display. The color scores of trained panelists for enhanced calf-fed Holstein steaks were more desirable ($P < 0.05$) for steaks from cattle not treated with ZH than for steaks from cattle treated with ZH for 20 d on d 1, 2, 3, and 4 of display. However, the discoloration scores of trained panelists for enhanced and modified-atmosphere-packaged calf-fed Holstein steaks were similar for steaks from cattle treated with ZH for 0 and 20 d on d 1, 2, and 3 of display. The scores of trained panelists indicated that traditionally packaged steaks from calf-fed Holsteins treated with ZH for 0 d had a darker lean color ($P < 0.05$) than steaks from ZH-treated cattle on d 1 of display, whereas the lean color scores for ZH treatments of all durations were similar on d 4 of display. The scores of trained panelists indicated that ZH treatment had no effect on the discoloration of traditionally packaged, nonenhanced strip steaks from calf-fed Holsteins. Therefore, feeding ZH to beef or calf-fed Holstein steers had no detrimental effect on the lean color or color stability of strip loin steaks subjected to enhancement, packaged in modified-atmosphere or traditional packaging, and displayed under simulated retail conditions.

Key words: β-adrenergic agonist, beef, display color, modified-atmosphere packaging, overwrap packaging, zilpaterol hydrochloride

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INTRODUCTION

Meat color is used by consumers to determine freshness, perceived eating quality, and desirability (Cassens et al., 1988). Consumers prefer a bright red lean

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color (Carpenter et al., 2001) and do not purchase beef steaks when lean surface metmyoglobin reaches 30 to 40% (Gee and Brown, 1980). Although fresh meat lean color and discoloration are not directly related to nutrition, microbiology, or quality (Zhu and Brewer, 1998), lean color continues to direct purchase decisions. Therefore, the approval of feed supplements that could affect consumer purchase decisions must be investigated.

Zilpaterol hydrochloride (**ZH**) belongs to a class of catecholamines known as β-2-agonists and was approved in the United States as a feed supplement in 2006 (US Food and Drug Administration, 2006). Several researchers have documented the effect of ZH supplementation on meat color and shelf life. Hilton et al. (2009) noted that supplementing beef steers with ZH for 30 d had no effect on L^* and hue angle values of traditionally packaged beef strip steaks but decreased a^*, b^*, and saturation index color values when compared with control steaks. Strydom et al. (2000) found that traditionally packaged LM steaks from South African cattle fed ZH for 30 and 50 d had more acceptable lean color scores than control steaks in dark storage. In a study comparing β-agonists, in which LM samples from beef steers treated with ZH for 33 d were frozen before postmortem aging, Avendaño-Reyes et al. (2006) noted that ZH-treated steaks had a^* values similar to control steaks. However, research is needed characterizing the effects of ZH feeding for short durations (20 d) on steaks in modern packaging systems and the effects of feeding ZH to US cattle types (calf-fed Holsteins). Therefore, 2 studies were conducted to determine the effect of ZH feeding duration (20 to 40 d) on the shelf life of strip loin steaks from beef and calf-fed Holstein types packaged in traditional and modified-atmosphere packaging (**MAP**) systems.

MATERIALS AND METHODS

Animal Care and Use Committee approval was not obtained for this study because samples were obtained from federally inspected slaughter facilities.

Animal Feeding and Raw Material Selection

For trial 1, beef crossbred steers (n = 118; selected from 1,073 animals on trial) randomly allocated to 4 feeding groups were fed a typical feedlot finishing diet supplemented with 6.8 g of ZH/ton (90% DM basis; Intervet, Millsboro, DE) for the last 0, 20, 30, or 40 d of the finishing period (Gunderson et al., 2009a). All cattle were implanted with Revalor-IS (80 mg of trenbolone acetate and 15 mg of estradiol; Intervet/Schering-Plough Animal Health, DeSoto, KS) upon arrival at the feedlot (d 0) and again on d 80. Cattle were removed from ZH supplementation and ZH was withdrawn for 3 d before slaughter at a commercial processing plant.

For trial 2, calf-fed Holstein steers (n = 132; selected from more than 2,300 animals on trial) were fed a typical finishing diet containing 6.8 g of ZH/ton (90% DM basis; Intervet/Schering-Plough Animal Health) for the last 0, 20, 30, or 40 d of the feeding period and ZH was withdrawn 3 d before slaughter (Gunderson et al., 2009b). Before arrival at the feed yard (−120 d), steers were implanted with Synovex-S (200 mg of progesterone and 20 mg of estradiol benzoate; Fort Dodge Animal Health, Overland Park, KS), which was followed by Revalor-IS (Intervet/Schering-Plough Animal Health) implant on arrival at the feed yard (d 0).

Carcasses from trials 1 and 2 were electrically stimulated (45 V) 30 min postmortem and chilled at 0 ± 2°C. Select (USDA), A-maturity beef carcasses (HCW = 324 to 439 kg) and calf-fed Holstein carcasses (HCW = 360 to 484 kg) were randomly selected from each ZH feeding duration (0, 20, 30, or 40 d of ZH supplementation) on d 1 postmortem (Gunderson et al., 2009a,b). Strip loins (Institutional Meat Purchase Specifications No. 180, USDA) were captured from 1 side of each carcass (n = 29 to 30 beef strip loins/ZH treatment; n = 31 to 35 calf-fed Holstein strip loins/ZH treatment), vacuum-packaged, and commercially shipped under refrigeration (1 to 3°C) to the Texas Tech University Gordon W. Davis Meat Science Laboratory.

Subprimal Processing

On d 7 (beef type) and 9 (calf-fed Holstein type) postmortem, subprimal purge loss was calculated using the procedures described by Gunderson et al. (2009a) and was calculated using the following formula: {[(weight of packaged subprimal, g − weight of empty bag, g) − weight of drained and blotted subprimal, g]/[(weight of packaged subprimal, g − weight of empty bag, g) × 100]}. Carcass processing times and shipping delays prohibited the processing of calf-fed Holstein subprimals at 7 d postmortem. Fat in excess of 2.5 mm was trimmed from strip loin subprimals and cut into 2 (anterior and posterior) nearly equal portions.

Enhancement

The anterior portion of each strip loin was designated for moisture enhancement. The portion was weighed immediately before injection with a multineedle injector (Gunther Pickling Injector, Model PI 16/32, Hausaunchrift, Dieburg, Germany). The ingredients in the enhancement solution were calculated to provide 0.3% sodium chloride, 0.35% phosphate (Brifisol 85 Instant, BK Giulini Corp., Simi Valley, CA) and 0.05% rosemary extract (NatureGuard Rosemary Extract, Newly Weds Foods Co./Norac, Edmonton, Alberta, Canada) in the final product at a 10% pump level. Injected strip loin portions were allowed to rest for 10 min before postinjection weights were taken to determine actual pump percentages. Pump percentages were calculated using the following equation: {[(pumped and drained cut weight − initial cut weight)/initial cut weight] × 100}. Data analysis indicated the average pump percentage for both trials was 9.5 ± 2.9%.

Steak Fabrication and Packaging

Approximately 15 to 20 min postinjection, three 2.54-cm-thick steaks were cut from the moisture-enhanced strip loin portions, weighed, and placed in white polypropylene trays [Cryovac-Sealed Air Corp., Duncan, SC; oxygen transmission rate (**OTR**) of <0.1 mL of oxygen/tray per 24 h at 22.8°C and 0% relative humidity; moisture vapor transfer (**MVT**) of 2.0 g of water vapor/645.2 cm^2 per 24 h at 37.8°C and 100% relative humidity) containing absorbent pads (Dri-Loc AC-50, Cryovac-Sealed Air Corp.). The trays were flushed with a mixture of 80% oxygen and 20% carbon dioxide and sealed with a high-barrier film (LID 1050, Cryovac-Sealed Air Corp., OTR of <25 mL of oxygen/m^2 per 24 h at 22.8°C and 100% relative humidity; MVT of <0.1 g of water vapor/645.2 cm^2 per 24 h at 4.4°C and 100% relative humidity; Cryovac-Sealed Air Corp.) using a gas-flush tray-sealing packaging machine (Model CV/VG-S, G. Mondini, Brescia, Italy). The oxygen-carbon dioxide gas mixture was achieved using a diaphragm gas mixer (Checkmate 9900, PBI Dansensor, Glen Rock, NJ). The composition of gases in the headspace of packages was verified in test packages (which were not part of the study) throughout packaging by using a headspace analyzer (Pac-Check model 333, Mocon, Minneapolis, MN). Packing proceeded if the test packages were within ±0.5% of the targeted oxygen and carbon dioxide concentrations. The MAP were put in dark refrigerated storage for 5 to 7 d for the calf-fed Holstein and beef types, respectively. The nonenhanced posterior portion of each strip loin was vacuum-packaged (Barrier Bag B620, Cryovac-Sealed Air Corp; OTR of 30 to 50 mL of oxygen/m^2 per 24 h at 22.8°C and 1 atm; MVT of 0.5 to 0.6 g of water vapor/645.2 cm^2 per 24 h at 37.8°C and 100% relative humidity) at a minimum of 850 mbar after weighing and was placed in dark refrigerated storage for 5 and 7 d for the calf-fed Holstein and beef types, respectively.

At 14 d postmortem, all MAP and traditionally packaged beef and calf-fed Holstein steaks were placed in retail display cases for lighted display. The MAP steaks were removed from dark storage and placed in the retail case. Nonenhanced strip loin portions were removed from their vacuum packaging, fabricated into 2.54-cm-thick steaks, and placed on 4S expanded polystyrene trays (Cryovac-Sealed Air Corp.) with absorbent pads (Dri-Loc AC-50, Cryovac-Sealed Air Corp.). Traditional packages were then made when trays were overwrapped with polyvinyl chloride film (OTR = 21,700 mL of oxygen/m^2 per 24 h; MAPAC L, Borden Packaging and Industrial Products, North Andover, MA) and placed in the retail case.

Retail Display

All packages were displayed for 5 d under continuous fluorescent lighting (2,140 to 2,515 lx) using high-output bulbs with a color temperature of 3,500 K and a color rendering index of 70 in coffin-style (Model M1, Hussmann Corp., Bridgeton, MO) and multideck (Model M3, Hussmann Corp.) retail display cases. Packages were not stacked or layered but were allowed their own space perpendicular to the light source. Packages were rotated daily from side to side and front to back in each case (coffin style) or shelf (multideck). Packages from each treatment were randomly allotted to each retail case type so that one-half of each treatment was represented in each case type. Case temperature was monitored throughout display by using remote-temperature data loggers (Multi-Trip, Temprecord, Monitor Company, Modesto, CA), and monitoring indicated the cases were maintained at 0.9°C ± 2.3°C.

Visual Color Evaluation

Both trained panelists (n = 6 to 13 panelists/d) and consumer panelists (n = 60 to 66 panelists/d) were used to evaluate aspects of color, including initial color, lean color, and lean discoloration, using verbally anchored scales (American Meat Science Association, 1991). Trained panelists were required to have a total error score of ≤60 on the Farnsworth-Munsell 100-Hue Test (Xrite, Grandville, MI). Analytical panelists were trained with representative samples by meat science faculty who attended a multiuniversity correlation session. Trained panelists evaluated the initial color of steaks (d 0 of display) by using a verbally anchored scale, scored in one-half-point increments (1 = purplish pink or red or reddish pink; 2 = bleached, pale red; 3 = slightly cherry red; 4 = moderately light cherry red; 5 = cherry red; 6 = slightly dark red; 7 = moderately dark red; 8 = dark red; 9 = very dark red). Steak color was evaluated by trained panelists on d 1, 2, 3, and 4 of display by using a verbally anchored scale, and also was scored in one-half-point increments (1 = very bright red or pinkish red; 2 = bright red or bright pinkish red; 3 = dull red or dull pinkish red; 4 = slightly dark red or slightly dark pinkish red; 5 = moderately dark red or moderately dark pinkish red; 6 = dark red to dark reddish tan or dark pinkish red to dark pinkish tan; 7 = tannish red or tannish pink; 8 = tan to brown). Surface discoloration was assessed by trained panelists on d 1, 2, 3, and 4 of retail display by using a 7-point verbally anchored scale (1 = no discoloration; 2 = slight discoloration (1 to 19%); 3 = small discoloration (20 to 39%); 4 = modest discoloration (40 to 59%); 5 = moderate discoloration (60 to 79%); 6 = extensive discoloration (80 to 99%) 7 = total discoloration (100%).

Consumer panelists were recruited locally and paid $20 to participate in the study. Consumer panelists evaluated steaks on d 1 and 3 of retail display. Panelists evaluated steaks in 3 sessions (approximately 20 panelists per session) on each sampling day and were not allowed to participate more than once. Each panelist was asked if he or she agreed with the statement, "The meat in this package has good color" (1 = very strongly agree; 2 = strongly agree; 3 = slightly agree; 4 = slightly disagree; 5 = strongly disagree; 6 = very strongly disagree) and if he or she would purchase the steak (1 = definitely would purchase; 2 = probably would purchase; 3 = probably would not purchase; 4 = definitely would not purchase) based solely on its lean color (American Meat Science Association, 1991).

Instrumental Color and Steak Purge Loss

Instrument color was measured at 3 locations on the displayed surface of each steak by using a portable spectrophotometer (Hunter Miniscan XE Plus, Model MSXP-4500C, Hunter Laboratories, Reston, VA) with illuminant A for CIE $L^*a^*b^*$ values, a standard observer angle of 10°, and a 2.54-cm aperture. The 3 scans were averaged for each steak and were used in the data analysis. Instrument calibration was performed before use at each sampling interval, using black glass and white tile plates according to the recommendations of the manufacturer. Hunter CIE $L^*a^*b^*$ values were recorded before MAP (d −1) and on d 0, 2, and 4 of retail display. The MAP steaks were removed from their packages and immediately evaluated for instrumental color values. Hunter CIE $L^*a^*b^*$ values were also recorded on d 0, 2, and 4 for steaks packaged in traditional packaging. The CIE $L^*a^*b^*$ values were used to calculate hue angle ($\tan^{-1} b^*/a^*$) and saturation index $[(a^{*2} + b^{*2})^{1/2}]$. At instrumental color sampling intervals, steaks were weighed and the measurements were used to calculate steak purge loss during retail display by using the following equation: [(initial steak weight, g − final blotted steak weight, g)/initial steak weight, g] × 100.

Statistical Analysis

The experimental design was a split plot, with the whole-plot experimental unit being a beef steer or calf-fed Holstein, to which feeding treatments were randomly assigned. Beef- or calf-fed Holstein-type steaks were the subplot experimental units assigned randomly to day of retail display. Visual and instrumental color traits were repeated measures taken on each steak. Data across packaging treatments and cattle type were analyzed separately. With the MIXED procedure (SAS Inst. Inc., Cary, NC), subsets of least squares means were subjected to pair-wise comparisons using the Fisher LSD procedure at the $P < 0.05$ level of significance, depending on which main effects and interactions were significant. Zilpaterol hydrochloride duration and day were the main effects tested. The interactions tested were ZH × day of display.

Table 1. The effect of zilpaterol hydrochloride[1] treatment duration on the initial color scores[2] of trained panelists on enhanced beef strip steaks packaged in high-oxygen (80% oxygen and 20% carbon dioxide) modified-atmosphere packaging and nonenhanced beef strip loin steaks packaged in traditional overwrap (trial 1)

Zilpaterol hydrochloride duration, d	Enhancement and packaging	
	Enhanced + modified atmosphere	Nonenhanced + overwrap
0	5.2	5.2[b]
20	5.2	5.0[ab]
30	5.3	4.8[a]
40	5.1	5.0[ab]

[a,b]Least squares means within a column lacking a superscript letter differ ($P < 0.05$).

[1]Zilpaterol hydrochloride (Intervet, Millsboro, DE) dose = 6.8 g/ton on a 90% DM basis.

[2]Initial color scores: 4 = moderately light cherry red; 5 = cherry red.

RESULTS AND DISCUSSION

Trial 1

Initial color scores for enhanced MAP steaks and nonenhanced traditionally packaged steaks are presented in Table 1. The data indicated ZH duration had no effect ($P > 0.05$) on the initial color of beef steaks packaged in high-oxygen packages. Similar results were obtained by Gunderson et al. (2009a), who found no differences in high-oxygen MAP semimembranosus beef steaks from cattle supplemented with ZH for 0, 20, 30, and 40 d. In contrast, Van Overbeke et al. (2009) showed that top sirloin butt steaks from cattle fed ZH for 30 d had smaller initial color scores than steaks from cattle fed ZH for 0, 20, and 40 d. Among the nonenhanced, traditionally packaged steaks, ZH supplementation for 0, 20, and 40 d produced similar initial color scores, which were significantly darker than strip loin steaks from cattle fed ZH for 30 d. These results differed from those of Gunderson et al. (2009a), which indicated no differences in initial color scores of traditionally packaged semimembranosus steaks attributable to ZH feeding duration. The initial color differences among muscles are likely the result of differing muscle fiber types and the metmyoglobin-reducing ability of these muscles when packaged in these systems. Although not statistically analyzed, it was noted that steaks packaged in high-oxygen MAP had scores equal to or greater (more red) than those packaged in traditional packaging, regardless of ZH treatment duration. Previous research has documented similar results (Behrends et al., 2003; Seyfert et al., 2005; Grobbel et al., 2008), which are likely due to the prevalence of oxymyoglobin resulting from an abundance of oxygen in the package.

The effects of ZH supplementation and day of retail display on the color scores of trained and consumer

Table 2. The effect of zilpaterol hydrochloride[1] treatment duration and retail display time on the sensory scores of trained and consumer panelists on enhanced beef strip steaks packaged in high-oxygen (80% oxygen and 20% carbon dioxide) modified-atmosphere packaging (trial 1)

	Zilpaterol hydrochloride duration, d			
Variable and day of display[2]	0	20	30	40
Trained panelist color score[3]				
d 1	3.0	3.0	2.9	2.9
d 2	3.4	3.4	3.2	3.2
d 3	4.0	4.2	4.1	4.0
d 4	4.2	4.3	4.3	4.3
Trained panelist discoloration score[4]				
d 1	1.0	1.1	1.0	1.1
d 2	1.1	1.1	1.2	1.1
d 3	1.2	1.3	1.3	1.2
d 4	1.3	1.5	1.5	1.3
Consumer panelist color score[5]				
d 1	2.2	2.4	2.2	2.3
d 3	2.4	2.5	2.5	2.3
Consumer panelist purchase intention[6]				
d 1	2.2	2.0	2.0	2.1
d 3	2.1	2.2	2.2	2.1

[1]Zilpaterol hydrochloride (Intervet, Millsboro, DE) dose = 6.8 g/ton on a 90% DM basis.

[2]Duration × display day, $P > F$.

[3]Trained panelist color scores: 2 = bright red; 3 = dull red; 4 = slightly dark red ($P = 0.3254$; SEM = 0.11).

[4]Trained panelist discoloration scores: 1 = none (0%); 2 = slight discoloration (1 to 19%; $P = 0.5187$; SEM = 0.07).

[5]Consumer panelist color scores (agreement with the statement "This meat has good color"): 2 = strongly agree; 3 = slightly agree ($P = 0.6477$; SEM = 0.11).

[6]Consumer panelist purchase intention: 2 = probably would purchase; 3 = probably would not purchase ($P = 0.3863$; SEM = 0.08).

panelists for enhanced beef strip steaks packaged in MAP are presented in Table 2. Results indicated that ZH treatment duration had no effect on the color ($P = 0.0062$) and discoloration ($P = 0.0507$) scores of trained panelists or on consumer panelist responses to lean color ($P = 0.4728$) and purchase intention ($P = 0.8307$). Similar results were obtained by Montgomery et al. (2009). However, Gunderson et al. (2009a) found that in the latter days of display (d 4 to 5), semimembranosus steaks from beef cattle supplemented with ZH for 0 and 40 d had increased color scores (darker red) when compared with steaks from cattle supplemented with ZH for either 20 or 30 d. The authors provided no explanation for the lack of a linear effect of ZH treatment duration on the color scores of trained panelists. As expected, trained panelist scores for ZH treatments of all durations increased as the display time increased. However, least squares mean values remained acceptable throughout display.

The effects of ZH supplementation and day of retail display on the color scores of trained and consumer panelists for nonenhanced beef strip steaks in traditional packaging are presented in Table 3. A ZH duration × day of display interaction ($P \leq 0.05$) existed for the color and discoloration scores of trained panelists. The results indicated that ZH duration had no effect on the color scores of trained panelists on d 1 of display. Supplementation of ZH for 20 and 30 d resulted in steaks with a more red lean color ($P < 0.05$) than 0 d of supplementation on d 2 and 3 of display. By d 4 of display, steaks from beef cattle fed ZH for 20 d were redder than those from beef cattle fed ZH for 0, 30, and 40 d. These results are similar to those of Hilton et al. (2009), who reported that ZH supplementation increased the LM color scores of trained panelists throughout a 5-d display period. The color scores of trained panelists indicated a decrease ($P < 0.05$) in redness as retail display increased for ZH treatments of all durations. These results agree with previous data indicating a decline in lean color during the retail display period for semimembranosus (Gunderson et al., 2009a) and LM steaks (Hilton et al., 2009) from cattle supplemented with ZH. Although previous research (Gunderson et al., 2009a) does not indicate a significant ZH duration × display day interaction for color or discoloration scores of trained panelists, Hilton et al. (2009) indicated that LM beef steaks from cattle fed ZH for 30 d were redder in color after a 5-d display period than were control steaks. In the current study, strip steaks obtained from beef cattle fed ZH for 20 d and packaged in traditional packages produced more favorable ($P < 0.05$) color scores than samples from beef cattle fed ZH for 0, 30, or 40 d at the end of the display period, indicating that 20 d of ZH supplementation had an advantage in lean color and color stability.

Table 3. The effect of zilpaterol hydrochloride[1] treatment duration and retail display time on the sensory scores of trained and consumer panelists on beef strip steaks packaged in traditional overwrap packages (trial 1)

	Zilpaterol hydrochloride duration, d			
Variable and day of display[2]	0	20	30	40
Trained panelist color score[3]				
d 1	$3.5^{a,w}$	$3.2^{a,w}$	$3.2^{a,w}$	$3.5^{a,w}$
d 2	$4.4^{b,x}$	$3.7^{a,x}$	$3.8^{a,x}$	$4.0^{ab,x}$
d 3	$4.8^{b,y}$	$4.2^{a,y}$	$4.3^{a,y}$	$4.5^{ab,y}$
d 4	$6.5^{b,z}$	$6.0^{a,z}$	$6.6^{b,z}$	$6.6^{b,z}$
Trained panelist discoloration score[4]				
d 1	$1.0^{a,x}$	$1.0^{a,x}$	$1.0^{a,x}$	$1.0^{a,x}$
d 2	$1.2^{a,x}$	$1.1^{a,x}$	$1.1^{a,x}$	$1.1^{a,x}$
d 3	$1.7^{a,y}$	$1.4^{a,y}$	$1.5^{a,y}$	$1.5^{a,y}$
d 4	$4.8^{b,z}$	$4.3^{a,z}$	$5.1^{b,z}$	$5.0^{b,z}$
Consumer panelist color score[5]				
d 1	2.4^{y}	2.2^{y}	2.3^{y}	2.4^{y}
d 3	4.0^{z}	3.5^{z}	3.7^{z}	3.9^{z}
Consumer purchase intention[6]				
d 1	2.1^{y}	2.0^{y}	2.1^{y}	2.1^{y}
d 3	3.0^{z}	2.8^{z}	2.9^{z}	3.0^{z}

[a,b]Least squares means in a row lacking a common superscript letter differ ($P < 0.05$).

[w–z]Least squares means in a column and sensory trait lacking a common superscript letter differ ($P < 0.05$).

[1]Zilpaterol hydrochloride (Intervet, Millsboro, DE) dose = 6.8 g/ton on a 90% DM basis.

[2]Duration × display day, $P > F$.

[3]Trained panelist color scores: 3 = dull red; 4 = slightly dark red; 5 = moderately dark red; 6 = dark red or dark reddish tan ($P = 0.0062$; SEM = 0.14).

[4]Trained panelist discoloration scores: 1 = none (0%); 2 = slight discoloration (1 to 19%); 4 = modest discoloration (40 to 59%); 5 = moderate discoloration (60 to 79%; $P = 0.0507$; SEM = 0.15).

[5]Consumer panelist color scores (agreement with the statement "This meat has good color"): 2 = strongly agree; 3 = slightly agree; 4 = slightly disagree ($P = 0.4728$; SEM = 0.14).

[6]Consumer panelist purchase intention: 2 = probably would purchase; 3 = probably would not purchase ($P = 0.8307$; SEM = 0.09).

The duration of ZH treatment had no effect ($P = 0.0507$) on the discoloration scores of nonenhanced, traditionally packaged steaks on d 1, 2, or 3 of display (Table 3). On d 4, steaks from cattle supplemented with ZH for 20 d had significantly ($P < 0.05$) less discoloration than those from cattle in the 0-, 30-, and 40-d ZH treatments. Discoloration scores were similar for ZH treatments of all durations on d 1 and 2 of display. By d 3 of display, discoloration scores were significantly greater ($P < 0.05$) for all treatments. After d 4 of display, all steaks exhibited moderate discoloration. The data indicated that lean discoloration had begun among all ZH treatments by d 3 of display and was clearly evident ($P < 0.05$) by d 4 of display. The marked increase ($P < 0.05$) in treatment means from d 2 to 4 of display was magnified by the lack of sampling times between the 24-h sampling intervals.

Duration of the ZH treatment had no effect on the color scores ($P = 0.4728$) or purchase intention ($P = 0.8307$) of consumer panelists for beef strip steaks packaged in traditional packages (Table 3). These data indicated that consumers found no color differences among steaks from ZH-treated cattle, and lean color was not a decisive factor in their purchase decision. These data further indicated that the effects of ZH treatment duration noted by trained panelists and instrumental evaluations were not of sufficient magnitude to be seen by consumers or to influence their purchase decision. The color scores of consumer panelists did become less favorable ($P < 0.05$) with increased display time for all treatments, and purchase intention scores were significantly smaller ($P < 0.05$) on d 3 of display compared with d 1 of display for ZH treatments of all durations.

Instrumental color values for enhanced and nonenhanced steaks are presented in Tables 4 and 5, respectively. A ZH duration × day of display interaction existed ($P < 0.05$) for all color values except L^* values for both enhancement and package types. The data indicated that L^*, a^*, b^*, and saturation values were similar for ZH treatments of all durations before enhancement, whereas steaks from cattle fed ZH for 20 d had smaller ($P < 0.05$) hue values than steaks from cattle receiving 0-, 30-, or 40-d ZH treatments (Table 4). For L^* values, enhanced beef steaks tended ($P = 0.0040$) to be lighter at production and at d 2 and 4 of storage when compared with d 0. Zilpaterol hydrochloride treatment differences were observed on d 0 and 2 of lighted display, indicating that steaks from cattle receiving the 30-d ZH treatment were lighter ($P < 0.05$; greater L^* values) in color than steaks from cattle receiving the 0-, 20-, and 40-d ZH treatments. However, on d 2 of display, steaks from cattle receiving the 0- and 40-d ZH treatments

Table 4. The effect of zilpaterol hydrochloride[1] treatment duration and retail display time on instrumental color values of enhanced beef strip steaks packaged in high-oxygen (80% oxygen and 20% carbon dioxide) modified-atmosphere packaging (trial 1)

	Zilpaterol hydrochloride duration, d			
Color value and day of display[2]	0	20	30	40
L^{*3}				
Before enhancement	$41.9^{a,x}$	$42.1^{a,y}$	$42.5^{a,y}$	$42.4^{a,x}$
d 0	$38.1^{b,w}$	$38.8^{ab,w}$	$40.1^{a,w}$	$38.7^{ab,w}$
d 2	$42.3^{a,x}$	$40.1^{b,x}$	$41.5^{ab,x}$	$42.0^{a,x}$
d 4	$42.5^{a,x}$	$42.2^{a,y}$	$42.2^{a,xy}$	$42.0^{a,x}$
a^{*4}				
Before enhancement	$27.6^{a,x}$	$28.0^{a,y}$	$27.5^{a,x}$	$27.8^{a,w}$
d 0	$26.6^{a,w}$	$26.4^{a,x}$	$26.8^{a,x}$	$27.2^{a,w}$
d 2	$28.3^{b,x}$	$25.2^{a,w}$	$25.1^{a,w}$	$27.3^{b,w}$
d 4	$28.0^{b,x}$	$27.1^{ab,x}$	$26.9^{a,x}$	$27.8^{ab,w}$
b^{*5}				
Before enhancement	$20.6^{a,w}$	$20.5^{a,y}$	$20.6^{a,x}$	$20.8^{a,x}$
d 0	$20.3^{a,w}$	$19.6^{a,x}$	$20.3^{a,x}$	$20.4^{a,w}$
d 2	$21.3^{c,x}$	$18.4^{a,w}$	$17.8^{a,w}$	$19.7^{b,w}$
d 4	$21.5^{b,x}$	$20.4^{a,y}$	$20.1^{a,x}$	$20.2^{a,w}$
Hue[6]				
Before enhancement	$36.7^{b,w}$	$36.1^{a,w}$	$37.0^{b,x}$	$36.8^{b,x}$
d 0	$37.3^{a,x}$	$36.6^{a,wx}$	$37.2^{a,x}$	$36.8^{a,x}$
d 2	$37.0^{b,wx}$	$36.1^{a,w}$	$35.4^{a,w}$	$35.9^{a,w}$
d 4	$37.6^{b,x}$	$37.0^{b,x}$	$37.1^{b,x}$	$36.1^{a,w}$
Saturation[7]				
Before enhancement	$34.5^{a,x}$	$34.7^{a,y}$	$34.4^{a,x}$	$34.8^{a,x}$
d 0	$33.4^{a,w}$	$33.0^{a,x}$	$33.7^{a,x}$	$34.0^{a,wx}$
d 2	$35.5^{c,y}$	$31.2^{a,w}$	$30.7^{a,w}$	$33.7^{b,w}$
d 4	$35.4^{b,xy}$	$34.0^{a,xy}$	$33.6^{a,x}$	$34.4^{ab,wx}$

[a–c]Least squares means in a row lacking a common superscript letter differ ($P < 0.05$).

[w–y]Least squares means within a column and color value lacking a common superscript letter differ ($P < 0.05$).

[1]Zilpaterol hydrochloride (Intervet, Millsboro, DE) dose = 6.8 g/ton on a 90% DM basis.

[2]Duration × display day, $P > F$.

[3]$P = 0.0040$; SEM = 0.60.

[4]$P < 0.0001$; SEM = 0.40.

[5]$P < 0.0001$; SEM = 0.29.

[6]$P < 0.0001$; SEM = 0.28.

[7]$P < 0.0001$; SEM = 0.47.

were lighter ($P < 0.05$) in color than steaks from cattle receiving the 20- and 30-d ZH treatments. The lack of significant differences in L^* values between ZH treatments in our study corresponds with data reported for nonenhanced beef steaks (Roussel Uclaf, 1995; Hilton et al., 2009). However, Strydom and Nel (1999) documented increased L^* values associated with ZH supplementation among several muscles, including the LM.

No differences ($P > 0.05$) in a^* values were observed between ZH treatments on d 0 of lighted display (Table 4). However, on d 2 of display, steaks from cattle treated with ZH for 0 and 40 d had greater a^* values ($P < 0.05$) than those from cattle treated with ZH for 20 and 30 d. By d 4 of display, steaks from cattle treated with ZH for 0 d had greater ($P < 0.05$) a^* values than those from cattle treated with ZH for 30 d but had a^* values similar to those from cattle treated with ZH for 20 and 40 d. Avendaño-Reyes et al. (2006) noted that nonenhanced steaks from ZH-treated cattle had significantly smaller a^* values than steaks from control cattle. Although statistical differences existed among treatments, these data suggest that no practical differences in a^* values could be attributed to treatment. This was likely due to the use of rosemary extract in the enhancement solution and the high-oxygen packaging. Day of display did not have a remarkable effect on a^* values among enhanced, MAP steaks. It was noted that steaks from cattle treated with ZH for 20 and 30 d had smaller a^* values ($P < 0.05$) on d 2 of display than on d 0. In addition, a^* values were similar on d 2 and 4 of display for steaks from cattle treated with ZH for 0 d, whereas a^* values for steaks from cattle treated with ZH for 40 d remained unchanged during the 4-d display.

No differences ($P > 0.05$) in b^* values were observed for any ZH treatment at d 0 of display (Table 4). Steaks from cattle treated with ZH for 20 and 30 d exhibited significantly decreased b^* values on d 2 of display than those from cattle treated with ZH for 0 or 40 d. All steaks from ZH-treated cattle were less yellow ($P < 0.05$) on d 2 of display than on d 0 and d 4, indicating a decrease in yellow color tones over the display

Table 5. The effect of zilpaterol hydrochloride[1] treatment duration and retail display time on instrumental color values of beef strip steaks packaged in traditional overwrap packages (trial 1)

	Zilpaterol hydrochloride duration, d			
Color value and day of display[2]	0	20	30	40
L^*[3]				
d 0	43.8	43.0	44.8	45.0
d 2	41.6	41.4	42.5	42.4
d 4	39.1	39.3	39.7	40.7
a^*[4]				
d 0	31.1[a,x]	30.9[a,x]	30.4[a,x]	30.5[a,x]
d 2	23.7[b,y]	25.9[a,y]	25.2[a,y]	25.0[a,y]
d 4	14.4[c,z]	18.2[a,z]	17.3[ab,z]	16.2[b,z]
b^*[5]				
d 0	22.5[b,x]	23.2[a,x]	22.7[ab,x]	22.4[b,x]
d 2	17.8[c,y]	19.8[a,y]	18.7[b,y]	18.7[b,y]
d 4	15.9[b,z]	17.2[a,z]	17.4[a,z]	16.5[ab,z]
Hue[6]				
d 0	36.0[b,x]	36.9[a,y]	36.7[ab,y]	36.3[ab,y]
d 2	37.0[a,y]	37.4[a,y]	36.5[a,y]	36.8[a,y]
d 4	48.0[a,z]	43.6[c,z]	45.3[b,z]	45.7[b,z]
Saturation[7]				
d 0	38.4[a,x]	38.6[a,x]	38.0[a,x]	37.8[a,x]
d 2	29.7[c,y]	32.6[a,y]	31.4[ab,y]	31.2[b,y]
d 4	21.5[c,z]	25.1[a,z]	24.6[a,z]	23.2[b,z]

[a–c]Least squares means in a row lacking a common superscript letter differ ($P < 0.05$).

[x–z]Least squares means within a column and color value lacking a common superscript letter differ ($P < 0.05$).

[1]Zilpaterol hydrochloride (Intervet, Millsboro, DE) dose = 6.8 g/ton on a 90% DM basis.

[2]Duration × display day, $P > F$.

[3]Main effect of zilpaterol hydrochloride treatment duration ($P = 0.0065$), with treatment means of 41.5,[a] 41.2,[a] 42.3,[b] and 42.7[b] for 0, 20, 30, and 40 d, respectively ($P = 0.3617$; SEM = 0.45).

[4]$P < 0.0001$; SEM = 0.38.

[5]$P = 0.0352$; SEM = 0.30.

[6]$P < 0.0001$; SEM = 0.36.

[7]$P < 0.0001$; SEM = 0.45.

period. These observations are supported by the reports of Seyfert et al. (2006) and Sawyer et al. (2007), who also documented smaller b^* values ($P < 0.05$) in semimembranosus beef steaks as retail display times increased. At the conclusion of the storage period (d 4), beef steaks from cattle treated with ZH for 0 d had greater b^* values than steaks from cattle treated with ZH for 20, 30, or 40 d.

Reported hue values indicated that steaks from cattle treated with ZH for 0 d tended to have greater values than steaks from cattle treated with ZH for 20, 30, and 40 d on each day of display, which would be indicative of greater lean discoloration (Table 4). Before enhancement and MAP, steaks from cattle treated with ZH for 20 d had smaller ($P < 0.05$) hue angle values than steaks from cattle in all other treatments. No differences ($P > 0.05$) in hue angle values were observed among ZH treatments on d 0 of display. By d 4 of display, steaks from cattle treated with ZH for 40 d had smaller ($P < 0.05$) hue angle values than steaks from cattle treated with ZH for 0, 20, or 30 d. Gunderson et al. (2009a) found that steaks from cattle treated with ZH for 0 d and enhanced semimembranosus beef steaks had smaller hue angle values than steaks from ZH-treated cattle, which was increasingly evident as display time increased. Nonetheless, these results indicate an advantage among steaks from cattle supplemented with ZH during the feeding period in lean discoloration (i.e., decreased hue angle values).

Saturation values were similar for all ZH treatments before and after (d 0) enhancement (Table 4). On d 2 and 4 of display, steaks from cattle treated with ZH for 0 d displayed greater saturation index values ($P < 0.05$; greater degree of red saturation) than steaks from cattle in all other ZH treatments. Avendaño-Reyes et al. (2006) also noted greater saturation index values in LM steaks from cattle treated with ZH for 0 d compared with steaks from cattle fed ZH for 33 d before slaughter. Among ZH treatments, steaks had greater saturation index values before enhancement and on d 4 of storage, with reduced ($P < 0.05$) values observed on d 0 and 2 of display. The increase in red saturation at the end of the storage period was not observed by Gunderson et al. (2009a), who reported a decrease in saturation values as display time increased. The decrease in saturation index in ZH-treated cattle, although statistically significant, was not of sufficient magnitude to be noticed by trained and consumer panelists. Although the data of Gunderson et al. (2009a) contradict these findings, consideration should be given to the effect of carcass chilling and the metmyoglobin-reducing ability (McKenna et al., 2005) of these muscles.

Data analysis of nonenhanced beef strip loin steaks from cattle fed ZH for 0, 20, 30, and 40 d indicated a lack of ZH duration × day of display interaction for L^* values (Table 5). However, L^* values were affected by ZH treatment and indicated that steaks from cattle supplemented with ZH for 30 and 40 d had greater ($P = 0.0065$) L^* values than steaks from cattle treated with ZH for 0 and 20 d. Gunderson et al. (2009a) observed that traditionally packaged beef semimembranosus steaks from cattle treated with ZH for 20 d had greater L^* values on d 0 of display than steaks from cattle treated with ZH for 40 d. Strydom and Nel (1999) noted increased L^* values of longissimus thoracis steaks from Bonsmara-type steers and bulls that were supplemented with ZH for 30 d. Avendaño-Reyes et al. (2006) indicated that L^* values of steaks from ZH-treated cattle were greater than those of steaks from control cattle, but they indicated that treatments had little effect on color values. Hilton et al. (2009), however, noted that 30 d of ZH supplementation had no effect on L^* values of steaks when compared with steaks from control cattle.

No differences ($P > 0.05$) in a^* values were observed among ZH treatments on d 0 of display (Table 5). However, a^* values decreased ($P < 0.05$) with increasing day of retail display for all ZH treatments. By d 2 of display, steaks from cattle treated with ZH for 0 d had decreased a^* values compared with steaks from cattle whose diets were supplemented with ZH. On d 4 of display, steaks from cattle treated with ZH for 0 d had the least ($P < 0.05$) a^* values among al ZH treatments. These data indicate that ZH-supplemented cattle had an advantage in red lean color over steaks from control cattle (d 0 of ZH) after d 2 of display. These results, however, are contradicted by those of Avendaño-Reyes et al. (2006), who indicated that steaks from ZH-treated cattle had smaller a^* values than steaks from control cattle. In addition, Hilton et al. (2009) reported decreased a^* values associated with ZH supplementation for 30 d compared with steaks from control cattle.

The data indicated that b^* values for steaks from cattle treated with ZH for 20 d were greater ($P < 0.05$) than those for steaks from cattle treated with ZH for 0 and 40 d on d 0 and 2 of display (Table 5). By d 4 of display, the b^* values of traditionally packaged steaks from cattle fed ZH for 20 and 30 d were greater ($P < 0.05$) than those of steaks from control cattle. Gunderson et al. (2009a) found that semimembranosus beef steaks from cattle treated with ZH for 40 d had significantly greater b^* values compared with control steaks. Hilton et al. (2009) noted decreased b^* values among traditionally packaged beef steaks from cattle supplemented with ZH for 30 d. Finally, analysis also revealed that b^* values decreased ($P < 0.05$) as the day of display increased for all ZH treatments.

Interaction means for hue angle values generally indicated that steaks from control cattle (0 d of ZH) exhibited more ($P < 0.0001$) discoloration (increased hue angle values) than steaks from cattle supplemented with ZH by the end of the display period (Table 5). Although steaks from cattle supplemented with ZH for 0 d did not differ significantly ($P > 0.05$) from steaks from cattle in other treatments at d 2 of storage, steaks from cattle supplemented with ZH for 0 d had greater ($P < 0.05$) hue angle values by d 4 of display than steaks from cattle fed ZH. Previous research has indicated a decrease in hue angle values in beef semimembranosus steaks from ZH-treated cattle compared with nontreated control cattle (Gunderson, et al., 2009a). Hilton et al. (2009) noted that ZH supplementation has no impact on hue angle in their study, whereas Strydom et al. (2000) found that LM steaks from ZH-treated cattle incurred less metmyoglobin formation during display, which was indicative of decreased discoloration.

No differences ($P > 0.05$) in saturation index were observed among ZH treatments on d 0 of display (Table 5). However, saturation index values were smaller (less vivid; $P < 0.05$) on d 2 and 4 of display for steaks from cattle with 0 d of ZH treatment compared with those from cattle in the 20-, 30-, and 40-d ZH treatments. By d 4 of display, steaks from cattle treated with ZH for 20 and 30 d had greater ($P < 0.05$) saturation index values than steaks from cattle treated with ZH for 0 or 40 d. The data also indicated that saturation index values decreased as the display time increased for all ZH treatments, with d 0 > d 2 > d 4 ($P < 0.05$). Hilton et al. (2009) showed that saturation index values were smaller for steaks from ZH-treated cattle supplemented for 30 d compared with those from control cattle. Their data are supported by those of Avendaño-Reyes et al. (2006), who noted decreased chroma values in steaks from ZH-treated cattle compared with control cattle. Strydom and Nel (1999), however, noted that saturation index values were greater in steaks from ZH-treated Bonsmara-type steers and bulls. Finally, Strydom et al. (2000) noted that saturation index values did not differ among steaks from cattle treated with ZH for 0, 30, and 50 d in their study. Although significant differences in color values existed between ZH treatment durations during display for traditionally packaged and MAP enhanced beef steaks, the color scores of trained and consumer panelists indicated that the magnitude of difference between ZH treatments was not sufficient to be observed in the retail case.

Trial 2

The initial color scores of trained panelists for enhanced and nonenhanced strip loin steaks from calf-fed Holsteins fed ZH for 0, 20, 30, or 40 d are presented in Table 6. The duration of ZH feeding had no effect ($P > 0.05$) on the initial color scores of enhanced and MAP calf-fed Holstein strip steaks. Nonenhanced, traditionally packaged steaks from cattle fed ZH for 40 d

Table 6. The effect of zilpaterol hydrochloride[1] treatment duration on initial color scores[2] of trained panelists on enhanced calf-fed Holstein strip steaks packaged in high-oxygen (80% oxygen and 20% carbon dioxide) modified-atmosphere packaging and nonenhanced calf-fed Holstein strip loin steaks packaged in traditional overwrap (trial 2)

Zilpaterol hydrochloride duration, d	Enhancement and packaging	
	Enhanced + modified atmosphere	Nonenhanced + overwrap
0	5.7	5.8^{b}
20	5.9	5.6^{b}
30	5.9	5.5^{b}
40	5.9	5.3^{a}

[a,b]Least squares means within a column lacking a common superscript letter differ ($P < 0.05$).

[1]Zilpaterol hydrochloride (Intervet, Millsboro, DE) dose = 6.8 g/ton on a 90% DM basis.

[2]Initial color score: 5 = cherry red.

had smaller initial color scores ($P < 0.05$) than steaks from cattle from other feeding durations. However, all treatments averaged scores equivalent to cherry red according to the verbally anchored scale. The results are similar to those of Gunderson et al. (2009b), who indicated no effect of ZH feeding duration on initial color scores of nonenhanced semimembranosus steaks from calf-fed Holsteins.

The color scores of trained and consumer panelists for enhanced and MAP calf-fed Holstein strip steaks from cattle fed ZH for 0, 20, 30, and 40 d are presented in Table 7. Data for steaks from cattle treated with ZH for 0 d indicated a lighter red lean ($P < 0.05$) on d 1 and 2 of display compared with steaks from cattle in other ZH treatments, with lean color scores similar to steaks from cattle treated with ZH for 30 d on d 3 and 4 of display. On d 4 of display, color scores were greater ($P < 0.05$) for steaks from cattle on the 20- and 40-d ZH treatments compared with steaks from cattle on the 0-d ZH treatment. Similarly, Gunderson et al. (2009b) showed that ZH treatments (0, 20, 30, and 40 d) had no effect on the lean color scores of trained panelists for MAP enhanced semimembranosus steaks until d 5 of display, when steaks from cattle in the 20-d ZH treatment were observed to have greater lean color scores than steaks from cattle in the 0-d ZH treatment. As expected, the color scores of trained panelists showed that the lean color darkened ($P < 0.05$) as the day of display increased from d 1 to 4 for all ZH treatments.

Table 7. The effect of zilpaterol hydrochloride[1] treatment duration and retail display time on the sensory scores of trained and consumer panelists on enhanced calf-fed Holstein strip steaks packaged in high-oxygen (80% oxygen and 20% carbon dioxide) modified-atmosphere packaging (trial 2)

Variable and day of display[2]	Zilpaterol hydrochloride duration, d			
	0	20	30	40
Trained panelist color score[3]				
d 1	$4.8^{a,w}$	$5.1^{b,w}$	$5.1^{b,w}$	$5.0^{b,w}$
d 2	$5.0^{a,x}$	$5.5^{b,x}$	$5.5^{b,x}$	$5.5^{b,x}$
d 3	$5.1^{a,x}$	$5.5^{b,x}$	$5.3^{ab,y}$	$5.5^{b,x}$
d 4	$5.5^{a,y}$	$5.9^{b,y}$	$5.6^{ab,z}$	$5.8^{b,y}$
Trained panelist discoloration score[4]				
d 1	$1.0^{a,w}$	$1.0^{a,w}$	$1.1^{a,w}$	$1.1^{a,w}$
d 2	$1.1^{a,w}$	$1.2^{ab,x}$	$1.5^{b,x}$	$1.3^{b,x}$
d 3	$1.1^{a,w}$	$1.4^{ab,x}$	$1.7^{b,x}$	$1.4^{b,x}$
d 4	$1.4^{a,x}$	$1.7^{b,y}$	$2.1^{c,y}$	$1.8^{b,y}$
Consumer panelist color score[5]				
d 1	2.0^{w}	2.1^{w}	2.2^{w}	2.3^{w}
d 3	2.3^{x}	2.8^{x}	2.8^{x}	2.8^{x}
Consumer panelist purchase intention[6]				
d 1	2.0^{w}	2.3^{w}	2.3^{w}	2.4^{w}
d 3	1.9^{w}	2.0^{x}	2.0^{w}	2.0^{x}

[a–c]Least squares means in a row lacking a common superscript letter differ ($P < 0.05$).

[w–z]Least squares means within a column and color value lacking a common superscript letter differ ($P < 0.05$).

[1]Zilpaterol hydrochloride (Intervet, Millsboro, DE) dose = 6.8 g/ton on a 90% DM basis.

[2]Duration × display day, $P > F$.

[3]Trained panelist color scores: 4 = slightly dark red; 5 = moderately dark red; 6 = dark red or dark reddish tan ($P = 0.0015$; SEM = 0.10).

[4]Trained panelist discoloration scores: 1 = none (0%); 2 = slight discoloration (1–19%; $P = 0.0008$; SEM = 0.11).

[5]Consumer panelist color scores (agreement with the statement "This meat has good color"): 2 = strongly agree; 3 = slightly agree ($P = 0.1764$; SEM = 0.16).

[6]Consumer panelist purchase intention: 1 = definitely would purchase; 2 = probably would purchase ($P = 0.8056$; SEM = 0.11).

The discoloration scores of trained panelists indicated an increase in discoloration of MAP calf-fed Holstein steaks as the display period progressed from d 1 to 4 (Table 7). Discoloration scores were similar for all ZH treatments on d 1 of display. However, steaks from calf-fed Holsteins supplemented with ZH for 0 d exhibited less ($P < 0.05$) discoloration than steaks from Holsteins supplemented with ZH for 20, 30, and 40 d on d 4 of display, whereas steaks from Holsteins supplemented with ZH for 0 and 20 d exhibited similar discoloration scores on d 1, 2, and 3 of display. The data indicated that steaks from Holsteins fed ZH for 30 d exhibited greater ($P < 0.05$) discoloration scores on d 4 of display compared with steaks from Holsteins fed ZH for 0, 20, and 40 d. Gunderson et al. (2009b) observed similar discoloration scores for enhanced steaks from cattle treated with ZH for 0, 20, 30, and 40 d on d 1, 2, and 3 of display, with steaks from cattle treated with ZH for 20 d having greater discoloration scores on d 4, 5, and 6 of display when compared with steaks from cattle treated with ZH for 0, 30, and 40 d. These data indicated that ZH supplementation had a negative effect on the color and discoloration scores assigned by trained panelists late in the display period.

Duration of ZH feeding had no effect on the lean color scores of consumer panelists (Table 7). Consumer panelist scores indicated that lean color declined ($P < 0.05$) as display time increased from d 1 to 3 for all ZH treatments. The purchase scores of consumer panelists indicated no significant day × treatment interaction ($P = 0.8056$). Duration of ZH feeding had no effect on the purchase intention scores of consumer panelists. Purchase intention scores did not change during display for steaks from calf-fed Holsteins supplemented with ZH for 0 and 30 d, whereas steaks from Holsteins on the 20- and 40-d ZH treatments declined ($P < 0.05$) with increased display time from d 1 to 3. These results indicate that consumers found no difference in lean color resulting from ZH feeding and that feeding ZH for 30 d had no impact on intention to purchase when steaks were enhanced and packaged in high-oxygen MAP.

The color scores of trained and consumer panelists for nonenhanced, traditionally packaged calf-fed Holstein strip steaks from ZH-supplemented cattle are presented in Table 8. The color scores of trained panelists indicated that steaks of Holsteins treated for 0 d with ZH had a darker lean color ($P < 0.05$) than steaks from Holsteins treated with ZH on d 1 of display, whereas the lean color scores for ZH treatments of all durations were similar on d 4 of display. The lean color scores of steaks from cattle treated with ZH for 20, 30, and 40 d were similar on d 2 and 3 of display, whereas steaks from cattle treated with ZH for 30 and 40 d had more desirable ($P < 0.05$) lean color scores than steaks from cattle treated with ZH for 0 d on display d 2 and 3, respectively. Van Overbeke et al. (2009) observed greater color scores (indicative of a darker lean color) for top sirloin butt steaks from cattle treated with ZH for 0 d and displayed for 2 to 5 d compared with steaks from ZH-treated cattle. Gunderson et al. (2009b) noted that ZH treatment had no effect on nonenhanced, traditionally packaged semimembranosus steaks during 4 d of retail display. The color scores also indicated that lean color darkened ($P < 0.05$) as the display time increased from d 1 to 4 for ZH treatments of all durations.

The discoloration scores of trained panelists indicated that ZH treatments did not have a significant effect on the discoloration of traditionally packaged, nonenhanced strip steaks from calf-fed Holsteins (Table 8). The lack of a ZH treatment effect indicates that ZH supplementation had no effect on color stability. Similar results were observed by Van Overbeke et al. (2009) on top sirloin butt steaks. Gunderson et al. (2009b) also found similar discoloration scores for cattle treated with ZH for 0, 20, 30, and 40 d on d 0, 1, and 3 of display, whereas steaks from cattle treated with ZH for 20 d had smaller discoloration scores on d 2 compared with cattle treated with ZH for 0 and 40 d. Day of display did have a significant impact on discoloration scores and showed that discoloration increased significantly ($P < 0.05$) each day of display for ZH treatments of all durations. Similar results were observed among traditionally packaged, nonenhanced beef steaks from trial 1.

The duration of ZH treatment had no effect on the color or purchase intention scores of consumer panelists on d 1 or 3 of display (Table 8). Day of display, however, did affect the color scores of consumer panelists and indicated that steak color became less acceptable ($P < 0.05$) as the display time increased from d 1 to 3. Likewise, the purchase intention scores of consumer panelists reflected a decline in acceptability resulting from display time, with steaks at d 3 of display being less likely to be purchased ($P < 0.05$) than steaks on d 1 of display. These data indicated that ZH treatment did not affect the color scores of consumer panelists or their purchase intention when steaks were traditionally packaged and displayed for up to 3 d. Similar consumer results were observed for beef LM steaks from trial 1.

Instrumental color values for enhanced calf-fed Holstein strip steaks are presented in Table 9. A ZH duration × day of display interaction ($P = 0.0006$) occurred for all instrumental values (L^*, a^*, b^*, hue angle, and saturation index). Data analysis indicated that steaks from cattle treated with ZH for 30 d had smaller ($P < 0.05$) L^* values before enhancement and on d 0 of display compared with steaks from cattle treated with ZH for 0 and 20 d. On d 2 of display, steaks from cattle fed ZH for 20 d had greater L^* values ($P < 0.05$) than steaks from cattle fed ZH for 30 and 40 d. By d 4 of display, there were no differences ($P > 0.05$) in L^* values among ZH treatments. Data analysis indicated that L^* values were not a good indicator of the decreased bright red lean observed by trained and consumer panelists. Gunderson et al. (2009b) also showed that ZH duration had no effect on L^* values of enhanced semimembranosus steaks packaged in high-oxygen MAP. Geesink et al. (1993), however, indicated that supplementing the

Table 8. The effect of zilpaterol hydrochloride[1] treatment duration and retail display time on the sensory scores of trained and consumer panelists for calf-fed Holstein strip steaks packaged in traditional overwrap packages (trial 2)

	Zilpaterol hydrochloride duration, d			
Variable and day of display[2]	0	20	30	40
Trained panelist color score[3]				
d 1	4.5[b,w]	4.4[a,w]	4.3[a,w]	4.2[a,w]
d 2	5.3[b,x]	5.2[ab,x]	5.0[a,x]	5.1[ab,x]
d 3	5.6[b,y]	5.4[ab,y]	5.3[ab,y]	5.2[a,x]
d 4	6.2[a,z]	6.2[a,z]	6.3[a,z]	6.0[a,y]
Trained panelist discoloration score[4]				
d 1	1.2[w]	1.2[w]	1.2[w]	1.2[w]
d 2	1.5[x]	1.6[x]	1.5[x]	1.6[x]
d 3	2.0[y]	2.0[y]	1.9[y]	2.0[y]
d 4	3.1[z]	3.0[z]	3.2[z]	3.0[z]
Consumer panelist color score[5]				
d 1	2.8[w]	2.7[w]	2.6[w]	2.7[w]
d 3	3.4[x]	3.5[x]	3.4[x]	3.4[x]
Consumer panelist purchase intention[6]				
d 1	2.2[w]	2.2[w]	2.1[w]	2.2[w]
d 3	2.7[x]	2.8[x]	2.7[x]	2.7[x]

[a,b]Least squares means in a row lacking a common superscript letter differ ($P < 0.05$).

[w–z]Least squares means in a column and sensory trait lacking a common superscript letter differ ($P < 0.05$).

[1]Zilpaterol hydrochloride (Intervet, Millsboro, DE) dose = 6.8 g/ton on a 90% DM basis.

[2]Duration × display day, $P > F$.

[3]Trained panelist color scores: 4 = slightly dark red; 5 = moderately dark red; 6 = dark red or dark reddish tan ($P = 0.0275$; SEM = 0.10).

[4]Trained panelist discoloration scores: 1 = none (0%); 2 = slight discoloration (1 to 19%); 3 = small discoloration (20 to 39%; $P = 0.9334$; SEM = 0.12).

[5]Consumer panelist color scores (agreement with the statement “This meat has good color”): 2 = strongly agree; 3 = slightly agree ($P = 0.8973$; SEM = 0.15).

[6]Consumer panelist purchase intention: 2 = probably would purchase; 3 = probably would not purchase ($P = 0.8644$; SEM = 0.10).

diets of veal calves with clenbuterol increased the veal L^* color values.

Enhanced calf-fed Holstein steaks from cattle fed ZH for 0 d had greater ($P < 0.05$) a^* values than steaks from Holsteins fed ZH for 20, 30, and 40 d before enhancement and during retail display (Table 9). Instrumental a^* values were similar ($P > 0.05$) for steaks from Holsteins fed ZH for 20, 30, and 40 d before enhancement and on d 0 of display. By d 2 of display, a^* values were greater ($P < 0.05$) for steaks from Holsteins fed ZH for 30 d than for steaks from Holsteins fed ZH for 20 and 40 d and were similar to steaks from Holsteins fed ZH for 20 d on d 4 of display. Instrumental a^* values were greatest ($P < 0.05$) for all ZH treatments on d 2 of display compared with d 0 and 4. These results contradict those of Gunderson et al. (2009b), who indicated that steaks from cattle fed ZH for 0 d had a^* values similar to steaks from ZH-treated cattle on d 0 of display, and had a^* values similar to steaks from cattle fed ZH for 30 and 40 d on d 5 of display.

Steaks from cattle fed ZH for 0 d had greater ($P < 0.05$) b^* values than did steaks from cattle fed ZH for 20, 30, and 40 d before enhancement and on d 2 and 4 of display (Table 9). Steaks from ZH treatments of all durations exhibited their greatest ($P < 0.05$) b^* values on d 2 of display and their least ($P < 0.05$) b^* values before enhancement. Gunderson et al. (2009b) and Van Overbeke et al. (2009) found no effect of ZH supplementation on the b^* values of enhanced semimembranosus or gluteus medius steaks from calf-fed Holsteins during 5 d of simulated retail display.

Steaks from calf-fed Holsteins supplemented with ZH for 0 d had smaller hue angle values ($P < 0.05$) than steaks from Holsteins fed the other ZH treatments on d 4 of display, indicating less discoloration (Table 9). However, before enhancement and on d 0 of display, steaks from Holsteins treated with ZH for 0 d had hue angle values similar ($P > 0.05$) to steaks from Holsteins supplemented with ZH for 20 and 40 d and had values similar ($P > 0.05$) to steaks from Holsteins supplemented with ZH for 30 and 40 d on d 2 of display. Gunderson et al. (2009b) showed that the duration of ZH treatments had no effect on hue angles for steaks on d 0 and 3 of display, whereas in the present study, steaks from Holsteins supplemented with ZH for 20 d had greater hue angle values on d 5 of display compared with steaks from Holsteins supplemented with ZH for 0, 30, and 40 d that were enhanced and packaged in high-oxygen MAP. Steaks from Holsteins fed ZH for 0 d exhibited greater ($P < 0.05$) saturation index values than steaks from Holsteins fed ZH for 20, 30, and 40 d before enhancement and on d 2 and 4 of display (Table

Table 9. The effect of zilpaterol hydrochloride[1] treatment duration and retail display time on instrumental color values of enhanced calf-fed Holstein strip steaks packaged in high-oxygen (80% oxygen and 20% carbon dioxide) modified-atmosphere packaging (trial 2)

	Zilpaterol hydrochloride duration, d			
Color value and day of display[2]	0	20	30	40
L^{*3}				
Before enhancement	$31.8^{ab,y}$	$32.3^{a,x}$	$31.2^{b,x}$	$31.8^{ab,x}$
d 0	$34.8^{a,w}$	$34.3^{ab,w}$	$32.9^{c,w}$	$33.7^{bc,w}$
d 2	$29.5^{ab,z}$	$30.4^{a,y}$	$28.5^{b,y}$	$29.0^{b,y}$
d 4	$33.0^{a,x}$	$32.9^{a,x}$	$32.7^{a,w}$	$33.4^{a,w}$
a^{*4}				
Before enhancement	$16.7^{a,z}$	$15.9^{b,y}$	$16.0^{b,z}$	$15.8^{b,z}$
d 0	$26.0^{a,x}$	$24.4^{b,w}$	$25.0^{b,x}$	$24.1^{b,x}$
d 2	$29.9^{a,w}$	$24.6^{d,w}$	$27.6^{b,w}$	$25.9^{c,w}$
d 4	$21.5^{a,y}$	$18.0^{bc,x}$	$18.7^{b,y}$	$17.5^{c,y}$
b^{*5}				
Before enhancement	$14.3^{a,z}$	$13.5^{b,z}$	$13.1^{b,z}$	$13.4^{b,z}$
d 0	$20.7^{a,x}$	$20.0^{ab,x}$	$20.1^{ab,x}$	$19.8^{b,x}$
d 2	$26.3^{a,w}$	$22.4^{d,w}$	$24.7^{b,w}$	$23.3^{c,w}$
d 4	$18.1^{a,y}$	$16.3^{b,y}$	$16.5^{b,y}$	$16.1^{b,y}$
Hue[6]				
Before enhancement	$40.6^{a,wx}$	$40.2^{a,x}$	$39.2^{b,x}$	$40.3^{a,x}$
d 0	$38.5^{a,y}$	$39.4^{a,y}$	$38.8^{a,x}$	$39.4^{a,y}$
d 2	$41.3^{b,w}$	$42.4^{a,w}$	$41.9^{ab,w}$	$42.1^{ab,w}$
d 4	$40.3^{b,x}$	$42.3^{a,w}$	$42.4^{a,w}$	$43.0^{a,w}$
Saturation[7]				
Before enhancement	$22.0^{a,z}$	$20.9^{b,z}$	$20.7^{b,z}$	$20.7^{b,z}$
d 0	$33.2^{a,x}$	$31.5^{b,x}$	$32.1^{ab,x}$	$31.2^{b,x}$
d 2	$39.9^{a,w}$	$33.3^{d,w}$	$37.1^{b,w}$	$34.9^{c,w}$
d 4	$28.1^{a,y}$	$24.3^{bc,y}$	$25.1^{b,y}$	$23.8^{c,y}$

[a–d]Least squares means in a row lacking a common superscript letter differ ($P < 0.05$).

[w–z]Least squares means within a column and color value lacking a common superscript letter differ ($P < 0.05$).

[1]Zilpaterol hydrochloride (Intervet, Millsboro, DE) dose = 6.8 g/ton on a 90% DM basis.

[2]Duration × display day, $P > F$.

[3]$P = 0.0006$; SEM = 0.40.

[4]$P < 0.0001$; SEM = 0.35.

[5]$P < 0.0001$; SEM = 0.25.

[6]$P < 0.0001$; SEM = 0.37.

[7]$P < 0.0001$; SEM = 0.42.

9). Overall, saturation index values were greater ($P < 0.05$) on d 2 of display than on d 0 and 4, and before enhancement for ZH treatments of all durations. Gunderson et al. (2009b) noted that duration of ZH treatments and day of display had no effect on saturation index values of enhanced inside round steaks packaged in high-oxygen MAP.

Instrumental color values for nonenhanced calf-fed Holstein strip steaks are presented in Table 10. A ZH duration × day of display interaction ($P < 0.0001$) occurred for all instrumental values (L^*, a^*, b^*, hue angle, and saturation index). Instrumental L^* values for ZH treatments of all durations were similar on d 0 of display, which corresponds with previous data for traditionally packaged top sirloin butt steaks from calf-fed Holsteins (Van Overbeke et al., 2009; Table 10). On d 2 of display, L^* values for steaks from cattle fed ZH for 20 and 40 d were similar and were greater ($P < 0.05$) than those for steaks from cattle treated with ZH for 0 and 30 d. By d 4 of display, however, steaks from cattle fed ZH for 0 and 30 d had greater ($P < 0.05$) L^* values than steaks from cattle treated with ZH for 20 and 40 d. Gunderson et al. (2009b) observed that the duration of ZH treatments had no effect on the L^* values of nonenhanced semimembranosus steaks that were traditionally packaged and displayed for up to 3 d. Hilton et al. (2009) observed that ZH supplementation had no effect on L^* values in beef steers. Avendaño-Reyes et al. (2006), however, indicated that ZH supplementation increased L^* values in beef steaks compared with those in control steaks in their study.

Instrumental a^* values for steaks from cattle treated with ZH for 0 d were similar ($P > 0.05$) to steaks from ZH-treated cattle on d 0 of display, but were smaller ($P < 0.05$) than those for steaks from ZH-treated cattle on d 4 of display (Table 10). On d 2 of display, steaks from cattle treated with ZH for 30 d had greater ($P < 0.05$) a^* values than steaks from cattle treated with ZH for 0, 20, and 40 d. As display time increased from d 0 to 4, a^* values declined ($P < 0.05$) for ZH treatments

Table 10. The effect of zilpaterol hydrochloride[1] treatment duration and retail display time on instrumental color values of calf-fed Holstein strip steaks packaged in traditional overwrap packages (trial 2)

Color value and day of display[2]	Zilpaterol hydrochloride duration, d			
	0	20	30	40
L^{*3}				
d 0	$38.9^{a,y}$	$38.4^{a,yz}$	$38.6^{a,y}$	$38.1^{a,y}$
d 2	$36.2^{b,z}$	$38.9^{a,y}$	$36.7^{b,z}$	$39.2^{a,y}$
d 4	$40.6^{a,x}$	$37.0^{b,z}$	$40.0^{a,x}$	$36.3^{b,z}$
a^{*4}				
d 0	$16.4^{a,y}$	$17.0^{a,y}$	$16.9^{a,y}$	$16.8^{a,y}$
d 2	$15.9^{b,y}$	$16.5^{b,y}$	$17.9^{a,x}$	$15.9^{b,yz}$
d 4	$9.0^{c,z}$	$12.2^{b,z}$	$12.9^{b,z}$	$15.2^{a,z}$
b^{*5}				
d 0	$15.8^{a,y}$	$16.1^{a,y}$	$16.0^{a,yz}$	$15.9^{a,y}$
d 2	$16.0^{ab,y}$	$16.3^{a,y}$	$16.5^{a,y}$	$15.2^{b,z}$
d 4	$14.9^{b,z}$	$14.8^{b,z}$	$15.4^{ab,z}$	$16.2^{a,y}$
Hue[6]				
d 0	$44.2^{a,z}$	$43.3^{a,z}$	$43.6^{a,z}$	$43.6^{a,z}$
d 2	$45.6^{a,y}$	$44.7^{a,y}$	$42.8^{b,z}$	$44.1^{ab,z}$
d 4	$59.0^{a,x}$	$51.0^{b,x}$	$50.3^{b,y}$	$47.0^{c,y}$
Saturation[7]				
d 0	$22.8^{a,y}$	$23.8^{a,y}$	$23.3^{a,y}$	$23.2^{a,y}$
d 2	$22.6^{b,y}$	$23.2^{ab,y}$	$24.4^{a,x}$	$22.0^{b,z}$
d 4	$17.4^{c,z}$	$19.2^{b,z}$	$20.2^{b,z}$	$22.3^{a,yz}$

[a–c]Least squares means in a row lacking a common superscript letter differ ($P < 0.05$).

[x–z]Least squares means within a column and color value lacking a common superscript letter differ ($P < 0.05$).

[1]Zilpaterol hydrochloride (Intervet, Millsboro, DE) dose = 6.8 g/ton on a 90% DM basis.

[2]Duration × display day, $P > F$.

[3]$P < 0.0001$; SEM = 0.64.

[4]$P < 0.0001$; SEM = 0.43.

[5]$P < 0.0001$; SEM = 0.29.

[6]$P < 0.0001$; SEM = 0.51.

[7]$P < 0.0001$; SEM = 0.50.

of all durations. Gunderson et al. (2009a) noted that on d 0 and 3 of display, traditionally packaged semimembranosus steaks had similar a^* values when cattle were fed ZH for 0, 20, 30, and 40 d. Avendaño-Reyes et al. (2006) indicated that beef steaks from ZH-treated cattle had significantly smaller a^* values than control steaks. In addition, Hilton et al. (2009) reported decreased a^* values associated with 30 d of ZH supplementation compared with steaks from control cattle.

No differences ($P > 0.05$) in b^* values for steaks from cattle fed ZH for 0, 20, or 30 d were observed on d 0, 2, and 4 of display (Table 10). These results are consistent with those reported by Gunderson et al. (2009b), who found no differences in b^* values for semimembranosus steaks from cattle treated with ZH for 0, 20, or 30 d on d 0 and 3 of display. However, Van Overbeke et al. (2009) noted an increase in b^* values for top sirloin butt steaks from cattle fed ZH for 20 d compared with cattle fed the 0-, 30-, and 40-d ZH treatments. With the exception of steaks from cattle fed ZH for 40 d, b^* values declined ($P < 0.05$) with increased display time (d 0 vs. d 4). These data are consistent with observations made on semimembranosus steaks by Gunderson et al. (2009b). Hilton et al. (2009), however, noted decreased b^* values in traditionally packaged beef steaks from cattle treated with ZH for 30 d.

Hue angle values for nonenhanced calf-fed Holstein strip steaks were similar ($P > 0.05$) for ZH treatments of all durations on d 0 of display (Table 10). By d 4 of display, steaks from cattle fed ZH for 0 d had greater ($P < 0.05$) hue angle values than cattle in the 20-, 30-, or 40-d ZH treatments, indicative of increased discoloration over time. Gunderson et al. (2009b) noted no differences in hue angle attributable to ZH treatment duration or day of display for traditionally packaged steaks, and Hilton et al. (2009) noted that ZH supplementation has no impact on hue angle values of beef steaks.

Saturation index values were similar for ZH treatments of all durations on d 0 of display for calf-fed Holstein strip steaks (Table 10). On d 2 and 4 of display, steaks from Holsteins fed ZH for 0 d had smaller ($P < 0.05$) saturation index values than steaks from Holsteins fed ZH for 30 d. Except for steaks from Holsteins fed ZH for 40 d, saturation index values were smaller ($P < 0.05$) on d 4 of display compared with d 0. Hilton et al. (2009) showed that saturation index values were smaller for steaks from cattle treated with ZH for

Table 11. The effect of zilpaterol hydrochloride[1] treatment duration on the percentage of purge loss of strip loin subprimal enhanced, modified-atmosphere-packaged steaks and nonenhanced, traditional overwrap-packaged steaks from beef and calf-fed Holsteins during storage and retail display

Trial and zilpaterol hydrochloride duration, d	Subprimal, strip loin	Steaks: Enhanced + modified atmosphere	Steaks: Nonenhanced + overwrap
Trial 1: beef			
0	1.9	3.0	2.2
20	2.5	2.7	2.1
30	2.4	2.6	2.1
40	2.2	2.7	2.3
SEM	0.3	0.4	0.2
Trial 2: calf-fed Holsteins			
0	2.4[a]	2.3	1.5
20	2.5[a]	2.3	1.4
30	3.4[b]	2.7	1.5
40	3.4[b]	2.7	1.4
SEM	0.4	0.1	0.1

[a,b]Least squares means within a column and type lacking a common superscript letter differ ($P < 0.05$).
[1]Zilpaterol hydrochloride (Intervet, Millsboro, DE) dose = 6.8 g/ton on a 90% DM basis.

30 d compared with those from control cattle. Their data are supported by Avendaño-Reyes et al. (2006), who noted decreased chroma values in steaks from ZH-treated cattle compared with those from control cattle. Strydom and Nel (1999), however, noted that saturation index values were greater in steaks from ZH-treated Bonsmara-type steers and bulls. Finally, Strydom et al. (2000) noted that saturation index values did not differ among steaks treated with ZH for 0, 30, or 50 d. Gunderson et al. (2009b) noted that the duration of ZH treatments had no effect on saturation index values in their study, whereas values decreased for all ZH treatments as the day of display increased.

A summary of the data from trial 2 indicated that significant differences in instrumental color values existed between ZH treatments of different durations for enhanced calf-fed Holstein steaks in traditional packaging and MAP. However, the color and purchase intention scores of consumer panelists indicated that the magnitude of difference between ZH treatments was not sufficient to be reflected in their scores.

Strip loin subprimal and steak purge loss values for beef and calf-fed Holsteins are presented in Table 11. For trial 1, data analysis indicated that the duration of ZH feeding had no effect ($P > 0.05$) on the percentage of purge loss for strip loin subprimals, enhanced strip steaks packaged in high-oxygen MAP, or nonenhanced traditionally packaged strip loin steaks subjected to simulated retail display. Except for subprimal purge loss, similar results were obtained for calf-fed Holstein strip steaks subjected to retail display. Calf-fed Holstein strip loin subprimals from animals treated with ZH for 0 and 20 d had less ($P < 0.05$) purge loss than strip loins from animals treated with ZH for 30 and 40 d.

In conclusion, the results from trials 1 and 2 indicated that ZH supplementation for 20, 30, and 40 d had no detrimental effect on the color and purchase intention scores of consumer panelists for beef or calf-fed Holstein strip steaks when processed in traditional packaging or enhanced and in a MAP system. Objective color scores from both trials indicated the colorimeter was able to detect ZH treatment differences in lean color that could not be observed by consumer or trained panelists. Furthermore, the instrumental data failed to reveal a clear trend or pattern regarding the effects of ZH feeding duration on lean color and discoloration. Although the instrumental data did not fully support the subjective panel data in this project, work with beef and calf-fed Holstein semimembranosus and gluteus medius steaks has reported similar findings and support our conclusion. Therefore, we conclude that ZH had no detrimental effect on the shelf life of beef and calf-fed Holstein LM steaks packaged in traditional packaging or MAP and subjected to simulated retail display for up to 5 d.

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