

# Moisture enhancement and blade tenderization effects on the shear force and palatability of strip loin steaks from beef cattle fed zilpaterol hydrochloride

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**ABSTRACT:** Two trials investigated zilpaterol hydrochloride (ZH) feeding duration, enhancement, blade tenderization, and postmortem aging effect on Warner-Bratzler shear force (WBSF; trial 1) and consumer sensory ratings (trial 2). For trial 1, USDA Select beef strip loins were obtained from carcasses of beef steers fed ZH (6.8 g/t on 90% DM) the last 0, 20, 30, or 40 d of the feeding period. One-half of each strip loin was enhanced (110%) with a brine solution, whereas the remaining portion was not enhanced. Both pieces were portioned into steaks, which were aged 7, 14, or 21 d for WBSF analysis. For trial 2, paired USDA Select beef strip loins were obtained from carcasses of beef steers fed ZH the last 0 or 20 d of feeding. Paired strip loins were fabricated into 4 pieces and assigned to control, moisture enhanced, blade tenderized, and blade tenderized + moisture enhanced treatments. Strip loin pieces were then portioned into steaks that were aged 14 or 21 d postmortem. Consumers panelists ( $n = 458$ ) indicated their like or dislike of tenderness, juiciness, flavor, and overall like of each sample using 8-point, verbally anchored scales, as well as tenderness and overall acceptability. With exception of 20 d ZH-treated steaks, results from trial 1 indicate WBSF values decreased ( $P$

$< 0.05$ ) with enhancement. Among enhanced steaks, steaks from cattle fed ZH for 20, 30, and 40 d had greater ( $P < 0.05$ ) WBSF values than controls. Among nonenhanced steaks, 20 d ZH-treated steaks had WBSF values similar to 0, 30, and 40 d ZH-treated steaks, whereas 30 and 40 d ZH-treated steaks had greater ( $P < 0.05$ ) WBSF values than controls. Postmortem aging for 21 d improved ( $P < 0.05$ ) WBSF values for all ZH durations when compared with 7-d aging treatments. Results from trial 2 indicate ZH feeding for 20 d had no effect on flavor scores, decreased tenderness scores ( $P < 0.05$ ), and tended ( $P < 0.10$ ) to decrease juiciness and overall like scores when compared with controls for steaks aged 14 d. After 21 d aging, steaks from 20 d ZH-fed cattle had reduced ( $P < 0.05$ ) tenderness, juiciness, and overall like scores and tended ( $P < 0.10$ ) to have decreased flavor scores when compared with controls. These results indicate enhancement improved WBSF, but was not sufficient to overcome the detrimental effect of ZH feeding duration on WBSF until steaks were aged for 21 d postmortem. Consumer scores indicate 20 d ZH feeding had no effect on overall acceptability, but decreased tenderness and tenderness acceptability scores when compared with controls.

**Key words:** beef, blade tenderization, consumer, enhancement, shear force, zilpaterol hydrochloride

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## INTRODUCTION

Meat palatability is defined as the tenderness, juiciness, and flavor of cooked meat products (Miller, 2004). Among these palatability traits, it is generally accepted

that meat tenderness is the primary determinant of consumer satisfaction. To guarantee meat tenderness, the industry has historically relied on carcass maturity, intramuscular fat content, and postmortem aging. To further improve meat tenderness and consistency, some segments of the meat industry have utilized additional technologies to improve the inherent tenderness of meat products. Among these, blade tenderization and moisture enhancement are the most commonly used technologies on whole muscle beef cuts. Although designed

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to improve inherently tender meat products, these technologies can also be used to manage tenderness and consistency among meat products.

Zilpaterol hydrochloride (**ZH**) belongs to a classification of catecholamines known as  $\beta$ -2-agonists. When supplemented to cattle,  $\beta$ -2-agonists act to increase feed efficiency and ADG without increasing DMI (Maltin et al., 1987; Schiavetta et al., 1990; Reeds and Mersmann, 1991). Increased HCW, dressing percentage, and LM area have also been observed with the supplementation of ZH (Ricks et al., 1984; Schiavetta et al., 1990; Chikhou et al., 1993a,b). Zilpaterol hydrochloride has also been documented to increase shear force values (Brooks et al., 2009; Hilton et al., 2009; Leheska et al., 2009) and decrease consumer tenderness scores (Mehaffey et al., 2009) of US Choice strip loin steaks aged 14 d postmortem. Thus, the objective of this research was to determine the effect of ZH feeding duration and postmortem tenderness interventions on Warner-Bratzler shear force (**WBSF**) and consumer sensory ratings of US Select strip loin steaks.

## MATERIALS AND METHODS

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

To complete the above objectives, 2 trials were conducted to characterize the effect of ZH supplementation on the WBSF and consumer sensory ratings of US Select strip loins subjected to moisture enhancement, blade tenderization, and postmortem aging.

### *Trial 1*

Select beef strip loins (IMPS #180, USDA, NAMP, 2007) were obtained from the carcasses of cross-bred beef steers that had been fed ZH (6.8 g/t on 90% DM; Intervet/Schering-Plough Animal Health, DeSoto, KS) for the last 0, 20, 30, or 40 d of the feeding period. Animals were slaughtered at a commercial processing facility. Zilpaterol hydrochloride feeding duration treatment groups were identified at slaughter, and identity was maintained throughout the grading and fabrication process. Strip loins ( $n = 30$  per ZH feeding duration) representing the top, middle, and bottom one-third of the Slight marbling score were taken only from carcasses with an overall maturity score of A and HCW ranging from 318 to 408 kg with 77 to 116 cm<sup>2</sup> LM area at the 12th rib. Vacuum-packaged strip loins were commercially transported to the Texas Tech University G.W. Davis Meat Science laboratory at 1 to 3°C. At 7 d postmortem, strip loins were fabricated into 2 equal portions and randomly assigned to moisture enhanced or nonenhanced treatment groups. Enhanced strip loin pieces were injected with a brine solution formulated to provide 0.3% sodium chloride (A. C. Legg Inc., Calera, AL), 0.35% sodium pyro- and polyphosphate blend (Brifisol 85 Instant, BK Giulini Corporation, Simi Val-

ley, CA), and 0.05% rosemary extract (NatureGuard B, Newly Weds Foods, Chicago, IL) in the final product at a 10% pump level (actual pump level =  $10.93 \pm 2.33\%$ ) using a multi-needle (Günther Model PI 16/32, Hausanschrift, Dieburg, Germany) pickle injector. The used brine solution was not captured or circulated through the system. Enhanced loins were allowed to rest for 30 min at 0 to 2°C before portioning. Enhanced and non-enhanced pieces were then portioned into 2.54-cm-thick steaks and randomly assigned to 1 of 3 postmortem aging treatments: 7, 14, or 21 d. Steaks were individually vacuum packaged (Cryovac B-620 bags, Sealed Air Corporation, Duncan, SC: oxygen transmission of 30 to 50 mL in an area of 1 m<sup>2</sup> over 24 h and 1 atm at 22.8°C; water vapor transmission of 0.5 to 0.6 g in an area of 645.2 cm<sup>2</sup> over 24 h at 37.8°C and 100% relative humidity) at a minimum of 850 mbar and stored in the absence of light at 0 to 2°C. Packaged steaks were then frozen at -20°C on their designated postmortem aging treatment and stored at -20°C until shear force analysis (less than 30 d).

Warner-Bratzler shear force analysis was conducted according to American Meat Science Association guidelines (AMSA, 1995). Steaks were removed from frozen storage and arranged in a single layer on shelving in a refrigerated room maintained at 2 to 4°C for 24 h. Thawed steaks were removed from their packaging, weighed, and internal temperatures were recorded. Steaks were cooked on preheated (177°C) grills (George Foreman Digital Grill, model GRP99, Applica Inc., Miramar, FL) to an internal temperature of 71°C. Temperature was monitored during cooking using calibrated temperature probes (Digi-Sense Thermometer, Type J Thermocouple, Cole-Parmer Instrument Company, Vernon Hills, IL). Cook time and yield were recorded for each steak (data not reported). Steaks designated for WBSF were placed on trays, covered with polyvinylchloride film, and held overnight (approximately 12 h) at 2 to 4°C. Six cores measuring 1.25-cm in diameter and taken parallel to muscle fiber orientation were obtained from each steak and sheared once, perpendicular to muscle fiber orientation on a Warner-Bratzler shear machine (G-R Elec. Mfg. Co., Manhattan, KS) equipped with a digital force gauge (Mecmesin BFG500N, G-R Elec. Mfg. Co.). Peak force (kg) was recorded for each core; the 6 cores were then used to calculate an average WBSF value for each steak.

### *Trial 2*

Paired USDA Select beef strip loins (IMPS #180, USDA, NAMP, 2007) were obtained from the carcasses of cross-bred beef steers that had been fed ZH (6.8 g/t on 90% DM) for the last 0 or 20 d of the feeding period. Animals were slaughtered at a commercial processing facility. Zilpaterol hydrochloride feeding duration treatment groups were identified at slaughter, and identity was maintained throughout the grading and fabrication process. Thirty paired strip loins were selected by the

**Table 1.** Demographics of consumers (n = 458 consumers) in the study

Demographic trait	Percentage of consumers
Sex	
Male	50.44
Female	49.56
Household size	
1 person	7.91
2 people	32.75
3 people	20.66
4 people	23.08
5 people	8.79
6 people	3.96
Over 6 people	2.86
Household income	
Single income	27.33
Dual income	72.67
Age, yr	
Under 18	0.22
18 to 34	31.80
35 to 50	35.75
Over 50	32.24
Ethnicity	
African American	0.66
White	82.31
Native American	0.87
Hispanic	15.28
Asian	0.22
Other	0.66
Average household income/yr	
Under \$20,000	5.71
\$20,000 to 29,999	7.03
\$30,000 to 49,999	22.64
\$50,000 to 69,999	20.22
\$70,000 to 100,000	29.45
Over \$100,000	14.95
Education	
No high school	3.93
High school	15.72
Some college	40.83
College	24.67
Postgraduate	14.85
Beef consumption in 1 wk	
None	0.22
1 to 2 times	24.25
3 to 4 times	45.20
5 to 6 times	22.49
7 or more times	7.86

same criteria as trial 1. Vacuum-packaged strip loins were commercially transported at 1 to 3°C to the Texas Tech University G.W. Davis Meat Science laboratory and stored in the dark at 0 to 2°C. At 14 d postmortem, the paired strip loins were fabricated into 4 equal portions and randomly assigned to the following treatment groups: control, enhanced, blade tenderized, and blade tenderized plus enhancement. Blade tenderization was applied, once, from the lean side (fat side down) with a Jaccard meat tenderizer (model H, Orchard Park, NY). Enhanced strip loin pieces were injected with a brine solution formulated as above at a 10% pump level using a Gunther (model PI 16/32, Hausanschrift) multi-needle pickle injector. For the combination treatment, strip loin pieces were enhanced after blade tenderiza-

tion. Enhanced loins were allowed to rest for 30 min at 0 to 2°C before portioning. All treatments were then portioned into 2.54-cm-thick steaks and randomly assigned to 14 or 21 d postmortem aging. Steaks were individually vacuum packaged (Cryovac B-620 bags; oxygen transmission of 30 to 50 mL in an area of 1 m<sup>2</sup> over 24 h and 1 atm at 22.8°C; water vapor transmission of 0.5 to 0.6 g in an area of 645.2 cm<sup>2</sup> over 24 h at 37.8°C and 100% relative humidity) and stored in the absence of light at 2 to 4°C until they were frozen at -20°C on their designated postmortem aging time. Packaged steaks were stored at -20°C until consumer sensory analysis could be conducted (less than 30 d).

Consumer sensory panelists (n = 458) were recruited from Lubbock, TX, and were served at a central location in 16 panels (n = 28 to 30 panelists per panel) over 4 d. No efforts were made to target a specific demographic group (Table 1). Each panelist was served 8 samples representing the 2 ZH feeding durations and 4 tenderness intervention technology combinations. Approximately one-half of the participants (n = 8 panels) consumed samples aged 14 d postmortem, whereas the remainder sampled steaks aged 21 d postmortem. Samples were served to panelists under fluorescent lighting in individual booths. Panelists were provided with a ballot, expectorant cups, utensils, and 2 palate cleansers (unsalted crackers and apple juice). Panelists indicated their like or dislike of tenderness, juiciness, and flavor, as well as their overall liking of each sample using 8-point, verbally anchored (like and dislike) scales similar to Mehaffey et al. (2009). The consumer scores were then converted to a numerical scales where 1 = extremely dislike and 8 = extremely like for data analysis. Panelists were also asked if the tenderness and overall like of each sample was acceptable (yes or no). Steaks were thawed and cooked using the same methodology as trial 1.

### Statistical Analysis

Data for trial 1 were analyzed using the MIXED model procedures (SAS Inst. Inc., Cary, NC). The statistical model included the independent variables of ZH feeding duration (0, 20, 30, or 40 d), moisture enhancement (enhanced or nonenhanced), postmortem aging (7, 14, or 21 d), as well as their interactions (Table 2). Steak identification was used as a random variable, and the class variables included cook yield. The degrees of freedom in the denominator were adjusted using the Satterthwaite procedure. Least squares means were separated using the PDIF option of SAS and considered significant at  $P < 0.05$ . Data for trial 2 were analyzed using the MIXED model procedures of SAS. Data across postmortem age (14 or 21 d) were analyzed separately because consumer panel were served within aging treatment. The statistical model included the independent variables of ZH feeding duration (0 or 20 d) tenderness intervention technology (control, enhanced, blade tenderization, or enhanced + blade tenderization)

**Table 2.** Test of fixed effects of zilpaterol hydrochloride<sup>1</sup> feeding duration (0, 20, 30, or 40 d), postmortem aging (7, 14, or 21 d), moisture enhancement (enhanced or nonenhanced), and their interactions on Warner-Bratzler shear force values

Effect	<i>P</i> > <i>F</i>
Zilpaterol hydrochloride duration	0.0046
Postmortem aging (age)	<0.0001
Zilpaterol hydrochloride × postmortem aging	0.0816
Enhancement	<0.0001
Zilpaterol hydrochloride × enhancement	0.0555
Enhancement × postmortem aging	<0.0001
Zilpaterol hydrochloride × postmortem aging × enhancement	0.8002

<sup>1</sup>Intervet/Schering-Plough Animal Health, DeSoto, KS.

and their interaction. Steak identification, steak identification × ZH treatment, and consumer identification (panel) were used as random variables. The degrees of freedom in the denominator were adjusted using the containment procedure. Least squares means were separated using the PDIF option of SAS and considered significant at  $P < 0.05$ . Tenderness and overall acceptability percentages were calculated for each panel using PROC FREQ of SAS. The data within each postmortem aging (14 or 21 d) group were then analyzed using the PROC GLIMMIX procedures of SAS using a model that included ZH feeding during, tenderness intervention, and their interaction. Percentage acceptability means for each treatment or treatment combination were separated using the PDIF option of SAS and considered significant at  $P < 0.05$ .

## RESULTS AND DISCUSSION

### Trial 1

Interaction least squares means for ZH feeding duration and moisture enhancement effects on WBSF are presented in Table 3. With the exception of 20 d ZH-treated steaks, WBSF values decreased ( $P < 0.05$ ) with enhancement. These results are similar to Vote et al. (2000) and McGee et al. (2002) who showed a decrease in WBSF of enhanced roasts and steaks compared with

nonenhanced controls. These results also agree with Sawyer et al. (2009), who indicated that 110% enhancement improved the WBSF of lamb loin chops and leg steaks compared with nonenhanced control steaks. Among enhanced steaks, ZH-treated steaks (20, 30, and 40 d ZH) had greater ( $P < 0.05$ ) WBSF values than control (0 d ZH) steaks. Among nonenhanced steaks, 20 d ZH-treated steaks had WBSF values similar to 0, 30, and 40 d ZH-treated steaks, whereas 30 and 40 d ZH-treated steaks had greater ( $P < 0.05$ ) WBSF values than 0 d ZH-treated steaks. Brooks et al. (2009) noted in a summary of 5 ZH feeding trials that WBSF values of USDA Select strip loin steaks from cattle fed ZH for 20 d were greater than 0 d ZH-treated steaks. The authors also showed 20 d ZH-treated steaks had less ( $P < 0.05$ ) WBSF values than 30 and 40 d ZH-treated steaks. However, Brooks et al. (2009) observed a similar trend in the WBSF of gluteus medius steaks from ZH-supplemented animals, which indicated no difference in WBSF between 0 and 20 d ZH-treated animals. These data indicate that ZH feeding increased the WBSF values of enhanced steaks.

Zilpaterol hydrochloride feeding duration by postmortem aging least squares interaction means for WBSF are shown in Table 4. Data analysis indicates WBSF of 20, 30, and 40 d ZH-treated steaks were greater ( $P < 0.05$ ) on 7 and 14 d postmortem age than 0 d ZH-treated steaks. However, after 21 d postmortem aging, the WBSF of US Select strip loin steaks from 0, 20 and 40 d ZH treatments were similar. Data analysis also indicated postmortem aging decreased ( $P < 0.05$ ) WBSF values as aging time progressed from 7 to 14 d for 0, 30, and 40 d ZH-treated steaks; and from 14 to 21 d for 20 d ZH-treated steaks. Increased aging from 14 to 21 d postmortem resulted in additional improvements ( $P < 0.05$ ) in WBSF for 30 and 40 d ZH-treated steaks. Brooks et al. (2009) did not observe a ZH feeding duration × postmortem aging interaction for USDA Select, nonenhanced strip loin, gluteus medius, or triceps brachii steaks. However, postmortem aging improved ( $P < 0.05$ ) the WBSF of USDA Select strip and triceps brachii steaks as postmortem aging progressed from 7 to 14 d and 14 to 21 d. These data indicate WBSF values improve as aging time increases for control and ZH-treated steaks. The improvement in WBSF attributed

**Table 3.** The effects of zilpaterol hydrochloride<sup>1</sup> feeding duration and moisture enhancement on the Warner-Bratzler shear force of US Select beef strip steaks (interaction *P*-value = 0.0555; SEM = 0.12 kg)

Enhancement	Zilpaterol hydrochloride feeding duration, d			
	0	20	30	40
Enhanced	2.76 <sup>a,x</sup>	3.28 <sup>b,x</sup>	3.38 <sup>b,x</sup>	3.12 <sup>b,x</sup>
Not enhanced	3.11 <sup>a,y</sup>	3.38 <sup>ab,x</sup>	3.63 <sup>b,y</sup>	3.51 <sup>b,y</sup>

<sup>a,b</sup>Least squares means within a row lacking a common superscript letter differ ( $P < 0.05$ ).

<sup>x,y</sup>Least squares means within a column lacking a common superscript letter differ ( $P < 0.05$ ).

<sup>1</sup>Zilpaterol hydrochloride (Intervet/Schering-Plough Animal Health, DeSoto, KS) dose = 6.8 g/t on 90% DM basis.

**Table 4.** The effects of zilpaterol hydrochloride<sup>1</sup> feeding duration and postmortem aging on the Warner-Bratzler shear force of US Select beef strip steaks (interaction *P*-value = 0.0816; SEM = 0.13 kg)

Postmortem age, d	Zilpaterol hydrochloride feeding duration, d			
	0	20	30	40
7	3.08 <sup>a,x</sup>	3.58 <sup>b,x</sup>	3.77 <sup>b,x</sup>	3.63 <sup>b,x</sup>
14	2.88 <sup>a,y</sup>	3.42 <sup>b,x</sup>	3.50 <sup>b,y</sup>	3.30 <sup>b,y</sup>
21	2.84 <sup>a,y</sup>	2.99 <sup>ab,y</sup>	3.23 <sup>b,z</sup>	3.01 <sup>ab,z</sup>

<sup>a,b</sup>Least squares means within a row lacking a common superscript letter differ ( $P < 0.05$ ).

<sup>x,z</sup>Least squares means within a column lacking a common superscript letter differ ( $P < 0.05$ ).

<sup>1</sup>Zilpaterol hydrochloride (Intervet/Schering-Plough Animal Health, DeSoto, KS) dose = 6.8 g/t on 90% DM basis.

to postmortem aging has been observed by several researchers. Strydom and Nel (1996) reported a decrease in shear force when ZH-treated steaks were aged from 7 to 14 d. Buys and Strydom (2000) observed a 10% improvement in shear force when steaks from ZH-treated animals were aged from 3 to 10-d postmortem. Finally, Hilton et al. (2009) reported WBSF decreased from 7 to 21 d postmortem among steaks from animals supplemented with ZH for 30 d. These data also indicate postmortem aging decreases the variation associated with ZH feeding and results in similar WBSF values between control 20 and 30 d ZH-treated steaks after 21 d. Finally, these data indicate WBSF improvements associated with postmortem aging are greater for 20, 30, and 40 d ZH-treated steaks than control steaks. This conclusion is also supported by Hilton et al. (2009) who reported a decrease in shear force attributed to postmortem aging of ZH treated beef from 7 to 21 d that exceeded the control group (1.35 kg reduction vs. 0.48 kg reduction for control steaks), therefore supporting the interaction between ZH feeding duration and postmortem aging observed in our study.

The effects of moisture enhancement and postmortem aging on WBSF are presented in Table 5. No difference in WBSF was observed between enhanced and nonenhanced control steaks at 7 d postmortem aging. However, WBSF was less ( $P < 0.05$ ) for enhanced steaks at 14 and 21 d postmortem age when compared

with nonenhanced steaks. Among enhanced steaks, postmortem aging improved ( $P < 0.05$ ) WBSF at 14 and 21 d compared with 7 d enhanced steaks. Among nonenhanced steaks, additional postmortem aging from 7 to 14 d did not improve ( $P < 0.05$ ) WBSF, whereas an additional week of aging (to 21 d) decreased ( $P < 0.05$ ) WBSF values. It can be concluded that enhancement improves shear values earlier in the postmortem aging process than control steaks. This conclusion is supported by Wicklund et al. (2005) who found that aged enhanced beef strip loins had less WBSF values than nonenhanced aged steaks.

### Trial 2

The effect of ZH feeding duration (0 and 20 d), blade tenderization, and enhancement on the consumer sensory scores of USDA Select beef strip steaks aged 14 d postmortem are presented in Table 6. Data analysis revealed no interactions between ZH feeding duration and tenderness intervention for consumer sensory traits. Feeding ZH for 20 d had no effect on consumer flavor scores, tended ( $P < 0.10$ ) to decrease juiciness and overall like scores, and decreased ( $P < 0.05$ ) tenderness scores when compared with controls. Mehaffey et al. (2009) reported 20 d ZH-treated USDA Select steaks aged 14 d postmortem had no impact on consumer scores for tenderness, juiciness, flavor, and overall like when compared with 0 d ZH-treated steaks. Tenderness intervention affected ( $P < 0.0001$ ) all consumer palatability scores. Consumer tenderness scores were significantly improved with the use of postmortem tenderness interventions (blade tenderization < enhancement < blade tenderization + enhancement;  $P < 0.01$ ). Enhancement, either alone or in combination with blade tenderization, improved ( $P < 0.01$ ) juiciness scores, whereas control steaks produced more desirable ( $P < 0.01$ ) juiciness scores than blade-tenderized steaks. Tenderness intervention treatments had similar effects on flavor and overall like scores as indicated by similar scores for control and blade-tenderized steaks, which were less ( $P < 0.01$ ) than enhanced and blade-tenderized + enhanced scores. Data analysis revealed no ZH feeding duration by tenderness intervention in-

**Table 5.** The effects of moisture enhancement and postmortem aging on the Warner-Bratzler shear force of US Select beef strip steaks (interaction *P*-value < 0.0001; SEM = 0.07 kg)

Postmortem age, d	Moisture enhancement	
	Enhanced	Not enhanced
7	3.53 <sup>a,x</sup>	3.50 <sup>a,x</sup>
14	2.99 <sup>a,y</sup>	3.56 <sup>b,x</sup>
21	2.89 <sup>a,y</sup>	3.16 <sup>b,y</sup>

<sup>a,b</sup>Least squares means within a row lacking a common superscript letter differ ( $P < 0.05$ ).

<sup>x,y</sup>Least squares means within a column lacking a common superscript letter differ ( $P < 0.05$ ).

**Table 6.** The effect of zilpaterol hydrochloride<sup>1</sup> feeding duration and meat tenderness intervention on the consumer sensory scores of beef strip steaks aged 14 d postmortem

Item	Duration (Dur), d			Tenderness intervention (TI)				<i>P</i> -value			
	0	20	SEM	Control	Blade	Enhanced	Blade/ enhanced	SEM	Dur	TI	Dur × TI
Tenderness <sup>2</sup>	5.7 <sup>a</sup>	5.3 <sup>b</sup>	0.10	4.8 <sup>a</sup>	5.3 <sup>b</sup>	5.7 <sup>c</sup>	6.3 <sup>d</sup>	0.10	0.0040	<0.0001	0.7260
Juiciness <sup>2</sup>	5.3	5.1	0.10	4.9 <sup>b</sup>	4.6 <sup>a</sup>	5.6 <sup>c</sup>	5.7 <sup>c</sup>	0.10	0.0800	<0.0001	0.8694
Flavor <sup>2</sup>	6.0	5.9	0.06	5.7 <sup>a</sup>	5.6 <sup>a</sup>	6.0 <sup>b</sup>	6.2 <sup>c</sup>	0.07	0.1253	<0.0001	0.0771
Overall like <sup>2</sup>	5.5	5.3	0.08	5.0 <sup>a</sup>	5.1 <sup>a</sup>	5.7 <sup>b</sup>	5.9 <sup>c</sup>	0.09	0.0705	<0.0001	0.8864
TendAcc <sup>3</sup>	82.6 <sup>a</sup>	75.7 <sup>b</sup>	1.99	67.8 <sup>a</sup>	74.6 <sup>a</sup>	83.1 <sup>b</sup>	91.1 <sup>c</sup>	2.81	0.0181	<0.0001	0.9627
OverAcc <sup>4</sup>	78.6	73.0	2.08	66.4 <sup>a</sup>	68.4 <sup>a</sup>	81.8 <sup>b</sup>	86.6 <sup>b</sup>	2.94	0.0594	<0.0001	0.8882

<sup>a-d</sup>Least squares means within a row lacking a common superscript letter differ ( $P < 0.05$ ).

<sup>1</sup>Zilpaterol hydrochloride (Intervet/Schering-Plough Animal Health, DeSoto, KS) dose = 6.8 g/t on 90% DM basis.

<sup>2</sup>Sensory scores were on an 8-point scale: 1 = extremely dislike and 8 = extremely like.

<sup>3</sup>Percentage of samples considered acceptable in tenderness by consumer panelists.

<sup>4</sup>Percentage of samples considered acceptable in overall liking by consumer panelists.

teractions for consumer tenderness and overall acceptability percentages. Consumer tenderness acceptability percentages were improved with the use of postmortem tenderness interventions (blade tenderization < enhancement < blade tenderization + enhancement;  $P < 0.05$ ) compared with controls. Overall acceptability percentages were similar for control and blade-tenderized steaks, but less ( $P < 0.05$ ) than enhanced and blade-tenderized + enhanced percentage acceptability. Zilpaterol hydrochloride feeding for 20 d reduced tenderness acceptability percentages and tended ( $P < 0.10$ ) to decrease overall acceptability scores. Mehaffey et al. (2009) noted a decrease of 5 and 4% in tenderness and overall acceptability percentages, respectively, for 20 d ZH-treated steaks compared with control USDA Select steaks aged 14 d postmortem.

The effects of ZH feeding duration and meat tenderness intervention on the consumer sensory scores of USDA Select beef strip steaks aged 21 d postmortem are presented in Table 7. Data analysis revealed no interactions between ZH feeding duration and tenderness intervention for consumer sensory traits, except juiciness (interaction means not reported). Feeding ZH for 20 d tended ( $P < 0.10$ ) to decrease flavor scores and decrease ( $P < 0.05$ ) tenderness, juiciness, and overall like scores compared with controls. These results contradict Mehaffey et al. (2009) who reported 20 d ZH-treated USDA Select steaks aged 21 d postmortem had no impact on consumer scores for tenderness, juiciness, flavor, and overall like when compared with 0 d ZH-treated steaks. Tenderness intervention affected ( $P < 0.0001$ ) all consumer palatability scores for steaks aged 21 d postmortem. Consumer tenderness scores were improved with the use of postmortem tenderness interventions (blade tenderization < enhancement < blade tenderization + enhancement;  $P < 0.01$ ) over control steaks. Enhancement, either alone or in combination with blade tenderization, improved ( $P < 0.01$ ) juiciness scores, whereas control steaks produced more desirable ( $P < 0.01$ ) juiciness scores than blade-tenderized steaks. Tenderness intervention treatments had similar

effects on flavor and overall like scores as indicated by similar scores for control and blade-tenderized steaks, which were less ( $P < 0.01$ ) than enhanced and blade-tenderized + enhanced scores. Data analysis revealed no ZH feeding duration and tenderness intervention interaction for consumer tenderness and overall acceptability percentages for USDA Select strip steaks aged 21 d postmortem. Control and blade-tenderized steaks had similar tenderness and overall acceptability percentages, which were less ( $P < 0.05$ ) than enhanced and blade-tenderized + enhanced percentages. Feeding ZH for 20 d decreased ( $P < 0.05$ ) tenderness acceptability percentages, but had no impact on overall acceptability percentages when compared with controls. Mehaffey et al. (2009) noted a decrease of 5 and 4% in tenderness and overall acceptability percentages, respectively, for 20 d ZH-treated steaks compared with control USDA Select steaks aged 21 d postmortem.

The tenderness interventions used in this study have documented effects on consumer sensory ratings. Hamling et al. (2008) found consumer sensory tenderness scores were greater for enhanced vs. nonenhanced steaks. Pietrasik and Shand (2005) reported significantly improved tenderness scores associated with blade tenderization. Juiciness scores have been shown to be greater in enhanced vs. nonenhanced steaks because of the moisture added at the time of injection (Grobbel et al., 2008). These results support the current study, which indicated both 14 and 21 d aged steaks from enhanced and blade-tenderized + enhanced treatments had significantly greater tenderness and juiciness scores than nonenhanced controls. Flavor scores observed in this study also agree with previous work showing sensory panel flavor ratings were greater for moisture injected steaks vs. noninjected treatments (Vote et al., 2000).

These data indicate ZH feeding duration, enhancement, and postmortem aging have an impact on the WBSF of USDA Select strip loin steaks and does not often affect shear force independently. Zilpaterol hydrochloride feeding duration increases the WBSF of

**Table 7.** The effect of zilpaterol hydrochloride<sup>1</sup> feeding duration and meat tenderness intervention on the consumer sensory scores of beef strip steaks aged 21 d postmortem

Item	Duration (Dur), d			Tenderness intervention (TI)					P-value		
	0	20	SEM	Control	Blade	Enhanced	Blade/ enhanced	SEM	Dur	TI	Dur × TI
Tenderness <sup>2</sup>	5.7 <sup>a</sup>	5.3 <sup>b</sup>	0.10	4.9 <sup>a</sup>	5.3 <sup>b</sup>	5.7 <sup>c</sup>	6.2 <sup>d</sup>	0.10	0.0078	<0.0001	0.3839
Juiciness <sup>2</sup>	5.1 <sup>a</sup>	4.8 <sup>b</sup>	0.10	4.6 <sup>b</sup>	4.3 <sup>a</sup>	5.5 <sup>c</sup>	5.5 <sup>c</sup>	0.10	0.0336	<0.0001	0.0053
Flavor <sup>2</sup>	6.0	5.9	0.06	5.7 <sup>a</sup>	5.7 <sup>a</sup>	6.2 <sup>b</sup>	6.3 <sup>b</sup>	0.07	0.0529	<0.0001	0.2872
Overall like <sup>2</sup>	5.6 <sup>a</sup>	5.4 <sup>b</sup>	0.08	5.0 <sup>a</sup>	5.1 <sup>a</sup>	5.8 <sup>b</sup>	6.0 <sup>b</sup>	0.09	0.0084	<0.0001	0.2264
TendAcc <sup>3</sup>	82.6 <sup>a</sup>	77.5 <sup>b</sup>	1.79	68.3 <sup>a</sup>	75.3 <sup>a</sup>	86.9 <sup>b</sup>	89.6 <sup>b</sup>	2.53	0.0498	<0.0001	0.7553
OverAcc <sup>4</sup>	78.6	74.7	1.81	67.7 <sup>a</sup>	70.8 <sup>a</sup>	83.7 <sup>b</sup>	84.6 <sup>b</sup>	2.57	0.1364	<0.0001	0.4680

<sup>a-d</sup>Least squares means within a row lacking a common superscript letter differ ( $P < 0.05$ ).

<sup>1</sup>Zilpaterol hydrochloride (Intervet/Schering-Plough Animal Health, DeSoto, KS) dose = 6.8 g/t on 90% DM basis.

<sup>2</sup>Sensory scores were on an 8-point scale: 1 = extremely dislike and 8 = extremely like.

<sup>3</sup>Percentage of samples considered acceptable in tenderness by consumer panelists.

<sup>4</sup>Percentage of samples considered acceptable in overall liking by consumer panelists.

enhanced and nonenhanced beef steaks, although 20 d ZH-treated steaks had similar WBSF to controls among nonenhanced steaks. Postmortem aging improves the WBSF of steaks from control and ZH-treated steaks, with the majority of improvement in WBSF observed in ZH-treated steaks. Aging for 21 d postmortem decreases differences between WBSF treatment means and results in statistically similar WBSF values between control, 20 d, and 40 d ZH-treated steaks. Enhancement accelerates the postmortem aging effect observed in WBSF values, when compared with nonenhanced controls, and results in decreased ( $P < 0.05$ ) WBSF than controls after 21 d aging. Zilpaterol hydrochloride feeding for 20 d decreased consumer tenderness scores for 14 and 21 d aged USDA Select steaks and decreased consumer juiciness and overall like scores. Enhancement and blade tenderization + enhancement interventions improved consumer tenderness, juiciness, flavor, and overall like scores for 0 and 20 ZH-treated steaks compared with controls. Blade tenderization improved consumer tenderness scores, but resulted in decreased ( $P < 0.05$ ) juiciness scores for 14 and 21 d aged strip loin steaks. Finally, consumer tenderness and overall acceptability percentages for 0 and 20 ZH-treated steaks, when compared with control (no intervention) were improved ( $P < 0.05$ ) with the use of enhancement and blade tenderization + enhancement, whereas ZH feeding treatment had no effect on overall acceptability scores for 14 and 21 d aged steaks.

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