The effects of zilpaterol hydrochloride on carcass cutability, tenderness, and sensory characteristics of calf-fed Holstein steers

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STORY IN BRIEF

To evaluate the impact of zilpaterol hydrochloride (ZH) on carcass cutability and tenderness of calf-fed Holstein steers, calf-fed Holstein carcasses (n = 102) were selected from a pool of 2,300 steers that were fed 0 or 8.3mg/kg (DM basis) ZH during the last 20 d of the finishing period with a 3 d withdrawal. Carcasses were selected based on carcass weight as well as predetermined USDA Yield Grade categories. For tenderness evaluation, steaks from the strip loin and top round were either used as a control or were injected with an enhancement solution and aged for 14 or 21 d. Carcasses from ZH fed steers had a greater amount of wholesale carcass lean than control fed steers. Additionally, ZH fed steers had a greater subprimal yield from the shoulder clod, strip loin, peeled tenderloin, top sirloin butt, bottom sirloin tri-tip, peeled knuckle, top inside round, bottom round flat, eye of round, heel and shank. Zilpaterol hydrochloride increased Warner-Bratzler Shear force values in strip loin steaks, regardless of aging period. In top round steaks aged for 21 d, ZH increased thaw loss, percent thaw loss, and percent cook loss. Enhancement decreased percent cook loss in strip loin steaks aged for both 14 and 21 d. Enhancement also decreased thaw loss and percent thaw loss in 21 d aged strip steaks. Shear force values were improved with enhancement in both 14 and 21 d aged strip steaks. Enhancement also improved WBS values for top round steaks aged for 21 d. Percent cook loss was also improved with enhancement in top round steaks aged for 14 and 21 d. Therefore, ZH can improve carcass cutability of calf-fed Holstein steers; however, ZH can negatively impact tenderness. Enhancement improved tenderness and some cooking characteristics and may be used to improve tenderness in ZH fed animals.

Key Words: zilpaterol hydrochloride, Holstein, cutability, tenderness, beef

INTRODUCTION

Zilpaterol hydrochloride (ZH), commercially available as Zilmax® (Intervet/Schering Plough, Millsboro, DE), is a beta-agonist recently approved for use in U.S. beef finishing diets. Zilpaterol hydrochloride is similar in nature to the catecholamines and acts as a repartitioning agent similar to other β-adrenergic agonists (β-AA). Zilpaterol hydrochloride is being marketed as a compound that can increase lean deposition and decrease fat accretion as well as improve animal growth performance characteristics much like the β-AA clenbuterol and cimaterol (Ricks et al., 1984; Chikhou et al., 1993).

As reported by Shook et al. (2009), ZH can increase the amount of wholesale lean recovered from the carcass; however, a reduction in tenderness in strip loin steaks resulting from ZH supplementation is also documented. While ZH has been shown to increase the lean yield in fed beef steers, limited research is available as to the effects on carcass yields from calf-fed Holstein steers. Calf-fed Holstein steers comprised nearly 9% of the total beef harvest in the U.S. that was surveyed by Smith et al. (2006) and typically are very consistent at producing a high percentage of USDA Choice or better carcasses. However, calf-fed Holstein steers typically have poor muscling, low dressing percentages, and reduced fabrication yields when compared to beef steers. Supplementing calf-fed Holstein steers with ZH in the final finishing phase may result in greater improvements in carcass yields than seen in traditional beef steers.

Improvements in beef tenderness have been reported using needle injected enhancement solutions in beef (Robbins et al., 2002). A recent report indicated that 19% of all fresh meat packages at the retail level have received some form of enhancement (National Cattlemen's Beef Association, 2007). The objectives of this experiment were to determine the effect of ZH on carcass cutability and tenderness from calf-fed Holstein steers as well as the impact of enhancement on products derived from calf-fed Holstein steers.

MATERIALS AND METHODS

Animals. Carcasses for this experiment were acquired from four different sources during two selection phases (2 sources/phase) at a large commercial feedlot in the desert Southwest U.S. from approximately 2300 calf-fed Holstein steers. Steers were either fed 8.3 mg/kg ZH (DM basis) for 20 d and were removed from the supplement 3 d prior to harvest; or fed a control (no ZH) diet. After harvest and chilling, carcasses were ribbed at the 12^{th} rib and carcass traits to determine USDA Quality (QG) and Yield Grades (YG) were recorded (USDA, 1997). After grading, carcasses were selected based on carcass weight and calculated yield grade. Carcasses were selected based on carcasses that were ± 1 SD (11.36 kg) from the mean hot carcass weight of the pen and to fit one of six predetermined USDA YG categories: YG < 1.99, YG 2 - 2.49, YG 2.5 - 2.99, YG 3 - 3.49, YG 3.5 - 3.99, and YG 4+ for both ZH supplemented and control cattle. After selection, carcass sides were transported 2,095 km via commercial refrigerated truck (0 to -2°C) to the Robert M. Kerr Food and Agriculture Products Center (FAPC) for further fabrication.

Carcass Fabrication. Once carcasses (n = 102) arrived at FAPC, they were stored in holding coolers (2° ± 2°C) until fabrication. Cold side weights (CSW) were recorded prior to fabrication using a certified rail scale. Carcasses were then fabricated into subprimals according to the North American Meat Processors Association (NAMP) guidelines typical to an industry standard cutout. Lean trimmings from all components were categorized into three categories: 90% lean/10% fat (90/10), 80% lean/20% fat (80/20), or 50% lean/50% fat (50/50) according to industry standard sorting techniques. Kidney knob fat, all trimmed fat, and all bones were also collected separately and weighed. Weights for all previously mentioned products of fabrication were also expressed as a percentage of CSW.

Muscle Selection and Enhancement. Upon completion of fabrication, strip loins (n = 54) and top inside rounds (n = 54) from Phase 1 were selected for subsequent enhancement and fabricated for shear force analysis. Strip loins and top rounds were cut into equal halves and within each subprimal, sections were allocated to either receive enhancement or to serve as the negative control by selecting alternation halves. The enhancement solution was formulated using a proprietary solution based on ongoing research at Oklahoma State University. Muscle halves allocated to enhancement were injected (10% by weight) and allowed to equilibrate for 15 min prior to steak fabrication.

Steak Fabrication and Aging. For each muscle sample, two 2.54 cm steaks were cut from the medial face and randomly assigned to one of two aging times (14 or 21 d) for objective tenderness determination. Additionally, two additional 2.54 cm steaks were cut from top rounds and strip loins and assigned to one of two aging times (14 or 21 d) for sensory evaluation. After fabrication, all steaks were individually vacuum packaged and aged for their respective time under refrigeration at 2° ± 2°C. After steaks had completed their appropriate aging time, they were frozen in a blast freezer (-30° ± 10°C) for 24 h, and then held in a subsequent freezer at 10° ± 2°C until further analysis.

Warner Bratzler Shear Force. Warner-Bratzler shear force (WBS) was completed using the American Meat Science Association guidelines (AMSA, 1995). Steaks were broiled on an impingement oven (XLT Impinger, Model 3240-TS, BOFI Inc., Wichita, KS) at 200ºC to an internal temperature of 68ºC. Steaks were covered and cooled overnight at 2º ± 2°C. Six cores, 1.27 cm in diameter, were removed parallel to muscle fiber orientation and sheared once, using a Warner-Bratzler head attached to an Instron Universal Testing Machine (Model 4502, Instron Corporation, Canton, MS). Peak load (kg) for all six cores was averaged and peak load (kg) was analyzed for each sample.

Sensory Panel. Sensory evaluation was conducted according to the guidelines set forth by the American Meat Science Association (AMSA, 1995).

Statistical Analysis. *Carcass Cutout Characteristics* - Data were analyzed using the mixed model procedures of SAS (SAS Inst. Inc., Cary, NC). Analysis of variance for a completely randomized design with the fixed main effect of ZH and random effect of individual carcass ID were included in the model. Carcass side was the experimental unit used for analysis. Least squares means were generated and separated using a pairwise t-test when the model displayed a treatment effect ($\alpha = 0.05$). All data for Phase 1 and Phase 2 were combined for analysis.

Shear Force and Steak Characteristics - Shear force and steak characteristics data were analyzed using the mixed model procedure of SAS using a completely randomized design with the fixed main effects of ZH, enhancement and ZH × enhancement interaction. Location (anterior vs. posterior) within each whole muscle was included into the model as a random effect. All data were analyzed by aging time. Least squares means were generated and separated using a pairwise t-test when the model displayed a treatment effect ($\alpha = 0.05$).

Trained Sensory Panel - Data collected from sensory panels were analyzed using the mixed model procedure of SAS using a completely randomized design with fixed main effects of ZH, enhancement, and ZH × enhancement interaction. Sample within session, location (anterior vs. posterior) within each muscle were included into the model as random effects. All data were analyzed by aging time. Least squares means were generated and separated using a pairwise t-test when the model displayed a treatment effect ($\alpha = 0.05$).

RESULTS AND DISCUSSION

Carcass Cutout. While carcasses from ZH steers had numerically greater cold side weights, total side weight was not impacted by ZH inclusion into the diet ($P = 0.27$) (Table 1). However, total wholesale carcass lean (total side weight minus 50/50 trim, 80/20 trim, 90/10 trim, kidney knob fat, total fat trim, and total bone) was increased ($P < 0.0001$) by nearly 5 kg and this increase resulted in a 2% increase in percent wholesale carcass lean when expressed on a carcass weight basis (Table 1). A significant reduction in total fat trim (*P* = 0.001) and total bone (*P* = 0.004) was also documented from carcasses of steers receiving ZH supplementation, resulting in a decrease in the percent of fat trim (*P* = 0.0003) and percent of bone (*P* < 0.0001) when expressed as a percent of carcass weight (Table 1). Moreover, there was no impact of ZH on any of the three lean trim levels measured. Finally, there was a tendency for ZH to decrease (*P* = 0.07) the amount of kidney knob fat; however, when expressed as a percentage of carcass weight, ZH supplementation significantly decreased (*P* = 0.03) kidney knob fat (Table 1).

Table 1. Effects of zilpaterol hydrochloride inclusion into the diet on the amount and percentage[1] of carcass cutout of calf-fed Holstein steers (n = 102).

	ZH[2]			
Trait	0	8.3mg/kg	Pr > F	SEM[3]
Total Side Weight, kg	171.55	173.26	0.27	1.10
Wholesale Carcass Lean, kg[3]	88.55	93.01	< 0.0001	0.78
Wholesale Carcass Lean, %	51.53	53.57	< 0.0001	0.08
50/50 Trim, kg	11.80	11.35	0.55	0.54
50/50 Trim, %	6.87	6.53	0.41	0.14
80/20 Trim, kg	3.02	3.42	0.18	0.22
80/20 Trim, %	1.76	1.98	0.13	0.06
90/10 Trim kg	12.09	12.63	0.24	0.33
90/10 Trim, %	7.04	7.30	0.32	0.09
Kidney Knob Fat, kg	6.48	6.04	0.07	0.17
Kidney Knob Fat, %	3.77	3.48	0.03	0.05
Total Fat Trim, kg	13.10	11.49	0.0014	0.35
Total Fat Trim, %	7.62	6.62	0.0003	0.09
Total Bone, kg	36.70	35.53	0.0036	0.28
Total Bone, %	21.40	20.52	< 0.0001	0.06

[1] % Listed as a percentage of cold side weight.
[2]ZH = Zilpaterol hydrochloride
[3] total side weight minus 50/50 trim, 80/20 trim, 90/10 trim, kidney knob fat, total fat trim, and total bone.

When comparing the subprimal yields from the forequarter, few differences due to ZH supplementation were observed. Shoulder clod weights increased (*P* = 0.0002) with ZH inclusion into the diet (8.70 kg vs. 9.30 kg). Also, the total yield of rib blade meat increased (*P* = 0.04) (1.34 kg vs. 1.43 kg) as well as the yield of the inside skirt increased (*P* = 0.0002) (1.08 kg vs. 1.20 kg) with ZH inclusion into the diet. When expressed as a percentage of carcass weight, ZH increased the percentage of the shoulder clod (*P* = 0.0001) (2.30% vs. 2.44%) and inside skirt (*P* = 0.0006) (0.29% vs. 0.31%). Zilpaterol also tended to increase (*P* = 0.07) the percentage of rib blade meat (0.35% vs. 0.38%).

In the hindquarter, numerous subprimals and muscles responded to ZH inclusion into the diet as recorded weights significantly increased. Weights increased for the strip loin (*P* < 0.0001) (4.09 kg vs. 4.50 kg), peeled tender (*P* < 0.0001) (2.54 kg vs. 2.83 kg), top sirloin butt (*P* = 0.01) (5.49 kg vs. 5.77 kg), bottom sirloin tri-tip (*P* < 0.0001) (0.86 kg vs. 0.95 kg), peeled knuckle (*P* = 0.001) (5.21 kg vs. 5.55 kg), top inside round (*P* < 0.0001) (9.28 kg vs. 9.99 kg), bottom round flat (*P* = 0.007) (6.16 kg vs. 6.53), eye of round (*P* < 0.0001) (2.15 kg vs. 2.39 kg), heel meat (*P* < 0.0001) (2.20 kg vs. 2.36 kg), and shank meat (*P* < 0.0001) (2.40 kg vs. 2.59 kg). Moreover, when expressed as a percentage of carcass weight, the percent yield increased for strip loin (*P* < 0.0001) (1.08% vs. 1.18%), peeled tender (*P* < 0.0001) (0.68% vs. 0.74%), top sirloin butt (*P* = 0.04) (1.46% vs 1.51%), bottom sirloin tri-tip (*P* = 0.0001) (0.23% vs. 0.25%), peeled knuckle (*P* = 0.001) (1.38% vs. 1.45%), top inside round (*P* = 0.0004) (2.46% vs. 2.62%), bottom round flat (P = 0.01) (1.63% vs. 1.71%), eye of round (P < 0.0001) (0.57% vs. 0.63%), heel meat (P = 0.0002) (0.58% vs. 0.62%), and shank meat (P = 0.0001) (0.64% vs. 0.68%) with ZH inclusion into the diet.

In the present study, an increase in wholesale carcass lean was documented and is similar to results reported by Hilton (2009) where calf-fed Holstein steers had a 1% increase in red meat yield when supplemented with ZH. Also, similar to results summarized by Hilton (2009), as well as Shook et al. (2009), subprimals from the forequarter showed less of a response to ZH supplementation as compared to subprimals of the hindquarter. In the present study, only one subprimal of major significance in the forequarter responded to ZH as compared to seven major subprimals that responded to ZH from the hindquarter. As previously reported by Smith et al. (1995) type II muscle fibers show a greater response to beta-agonist stimulation, and therefore, muscles with a greater amount of type II fibers will have a greater response to beta-agonist supplementation. Kirchofer et al. (2002) previously reported that the muscles from the chuck have a wide variety of muscle fiber types, moreover, they documented that the muscles from the round are mostly comprised of type II (white) muscle fibers. With a greater amount of type II fibers present in the round, it can be concluded that beta-agonist would have a greater influence on the muscles of the rounds as compared to the muscles of the chuck.

Steak Characteristics and Shear Force

14 d Aged Strip Loin Steaks. Steaks from control animals were more tender (P < 0.001) when compared to steaks from ZH fed animals (2.85 kg vs. 3.73 kg, respectively) and enhanced steaks had lower shear force values (P < 0.001) when compared to non-enhanced steaks (2.73 kg vs. 3.86 kg, respectively). However, mean WBS values for steaks, regardless of treatment, were below a tenderness threshold of ≤ 4.50 kg established in strip loin steaks by Miller et al. (2001).

21 d Aged Strip Loin Steak. Steaks from control animals were more tender (P < 0.0001) than those from ZH supplemented animals (2.82 kg vs. 3.39 kg, respectively) and enhanced steaks were more tender (P < 0.0001) than non-enhanced steaks (2.64 kg vs. 3.58, kg respectively). Regardless of treatment, mean WBS values remained below ≤ 4.50 kg, which was established by Miller et al. (2001) as the upper limit for being considered tender.

14 d Aged Top Round Steaks. An interaction between diet and enhancement was significant (P = 0.008) for WBS values. Warner-Bratzler shear values were greatest in ZH steaks that had not been enhanced (6.22 kg) and were lowest in enhanced steaks from both ZH supplemented (4.23 kg) and control animals (4.05 kg), while control, non-enhanced steaks were less tender than both enhanced control and enhanced ZH steaks, yet were more tender than non-enhanced steaks from ZH fed animals (5.07, kg).

21 d Aged Top Round Steaks. Steaks from ZH supplemented animals tended to be tougher (P = 0.10) when compared to steaks from control animals (4.67 kg vs. 4.39 kg, respectively) and steaks that were enhanced were more tender (P < 0.0001) when compared to non-enhanced steaks (3.95 kg vs. 5.11 kg, respectively). Additionally, steaks from animals not fed ZH as well as those that were enhanced had the only mean WBS value that was below the ≤ 4.50 kg threshold determined by Miller et al. (2001) which distinguished tender from intermediately tough.

Trained Sensory Panel. Strip loin steaks from ZH fed steers were considered less juicy ($P \leq 0.01$) for both initial and sustained juiciness at both 14 and 21 d of aging as determined by trained sensory panelists (Table 2). Moreover, panelists rated strip steaks from ZH fed steers aged for both 14 and 21 d lower ($P \leq 0.02$) in overall tenderness as compared to steaks from control animals (Table 2). Also, panelists indicated a greater ($P = 0.01$) amount of connective tissue in strip steaks from ZH fed animals regardless of postmortem aging time when compared to steaks from control animals (Table 2). Finally, strip steaks aged for 14 d from ZH fed steers had reduced painty/fishy ($P = 0.07$), and increased salty ($P = 0.10$) flavors as compared to steaks from control animals (Table 2). Enhancement improved ($P < 0.001$) initial juiciness in strip loin steaks aged 14 d yet only tended to improve ($P = 0.09$) initial juiciness in strip steaks aged for 21 d. Nonetheless, sustained juiciness was improved ($P < 0.001$) by enhancement in all strip steaks (Table 2). Regardless of aging time, overall tenderness was increased ($P < 0.0001$) with enhancement, and enhancement also reduced ($P < 0.0001$) the amount of connective tissue perceived by panelists (Table 2). Enhancement reduced both beefy and painty/fishy flavor intensities as panelist rated enhanced steaks, regardless of aging time, lower ($P < 0.001$) in beefy and lower ($P \leq 0.02$) in painty/fishy flavor (Table 2). Additionally, enhanced steaks aged 21 d were rated as having a lower ($P = 0.004$) livery/metallic flavor as compared to non-enhanced steaks (Table 2). Finally, all enhanced strip steaks, regardless of aging time, were rated as saltier ($P < 0.001$) when compared to non-enhanced strip steaks (Table 2).

Table 1. Effects of zilpaterol hydrochloride inclusion into the diet and enhancement on sensory characteristics of strip loin steaks.

	ZH			Enhancement			
Trait	0	8.3mg/kg	Pr > F	E	NE	Pr > F	SEM
14 d aging							
Initial Juiciness[1]	5.37	4.97	0.0008	5.57	4.76	< 0.001	0.08
Sustained Juiciness[1]	5.18	4.61	< 0.0001	5.35	4.45	< 0.001	0.08
Initial Tenderness[2]	6.10	6.61	0.61	6.48	6.23	0.80	0.70
Overall Tenderness[2]	6.03	5.68	0.001	6.41	5.31	< 0.0001	0.08
Connective Tissue[3]	6.15	5.86	0.01	6.54	5.47	< 0.0001	0.08
Beef Flavor[4]	2.22	2.13	0.09	1.72	2.63	< 0.0001	0.03
Painty/Fishy Flavor[4]	1.07	1.03	0.07	1.03	1.08	0.02	0.01
Livery/Metallic[4]	1.07	1.07	0.78	1.05	1.09	0.12	0.02
Salty[4]	1.65	1.75	0.10	2.35	1.05	< 0.001	0.04
21 d aging							
Initial Juiciness[1]	5.13	4.93	< 0.0001	5.36	4.70	0.09	0.08
Sustained Juiciness[1]	4.89	4.59	0.01	5.12	4.36	< 0.0001	0.08
Initial Tenderness[2]	6.71	5.75	0.17	6.43	6.02	0.56	0.49
Overall Tenderness[2]	6.03	5.84	0.02	6.50	5.37	< 0.0001	0.12
Connective Tissue[3]	6.21	5.98	0.01	6.61	5.58	< 0.0001	0.10
Beef Flavor[4]	2.19	2.13	0.21	1.74	2.58	< 0.0001	0.03
Painty/Fishy Flavor[4]	1.10	1.07	0.12	1.06	1.11	0.008	0.01
Livery/Metallic[4]	1.09	1.07	0.37	1.05	1.11	0.004	0.01
Salty[4]	1.62	1.69	0.12	2.30	1.01	< 0.0001	0.03

[1] 1 = Extremely dry; 8 = Extremely Juicy
[2] 1 = Extremely tough; 8 = Extremely Tender
[3] 1 = Abundant; 8 = None
[4] 1 = Not detectable; 3 = Strong

Overall tenderness was rated lower ($P = 0.04$) by panelist in top round steaks from ZH fed steers aged 14 d as compared to steaks from control animals (Table 3). Additionally, steaks from ZH fed steers aged for 21 d were rated as having less ($P = 0.002$) beef flavor as compared to controls (Table 3). Regardless of aging time, enhancement improved ($P < 0.0001$) initial and sustained juiciness, overall tenderness and the amount of detected connective tissue (Table 3). However, regardless of aging time, panelists rated enhanced top round steaks as having less (P < 0.0001) beef flavor and less ($P \leq 0.004$) painty/fishy flavor (Table 3). Moreover, livery/metallic flavors tended (P = 0.06) to be reduced in enhanced top round steaks aged for 14 d and the livery/metallic flavor was reduced (P = 0.01) in enhanced top round steaks aged 21 d (Table 3). Enhancement increased (P < 0.001) the saltiness of enhanced top round steaks aged for 14 d (Table 3), and for top round steaks aged 21 d, the salty flavor was greatest (P = 0.02) in control, enhanced steaks (2.09 ± 0.07) as compared to ZH enhanced (1.67 ± 0.07), and control and ZH nonenhanced steaks (1.08 ± 0.07 and 1.00 ± 0.07, respectively).

Table 3. Effects of zilpaterol hydrochloride inclusion into the diet and enhancement on sensory characteristics of top round steaks.

	ZH			Enhancement			
Trait	0	8.3mg/kg	Pr > F	E	NE	Pr > F	SEM
14 d aging							
Initial Juiciness[1]	4.97	4.81	0.19	5.29	4.50	< 0.0001	0.17
Sustained Juiciness[1]	4.80	4.80	0.99	5.32	4.28	< 0.0001	0.28
Initial Tenderness[2]	4.91	4.16	0.06	5.40	4.16	< 0.0001	0.24
Overall Tenderness[2]	4.87	4.61	0.04	5.35	4.14	< 0.0001	0.29
Connective Tissue[3]	4.79	4.60	0.12	5.22	4.17	< 0.0001	0.38
Beef Flavor[4]	2.41	2.34	0.28	2.00	2.76	< 0.0001	0.06
Painty/Fishy Flavor[4]	1.05	1.05	0.85	1.03	1.08	0.004	0.01
Livery/Metallic[4]	1.04	1.05	0.60	1.03	1.06	0.06	0.01
Salty[4]	1.46	1.57	0.13	1.99	1.03	< 0.001	0.06
21 d aging							
Initial Juiciness[1]	4.95	4.72	0.08	5.21	4.45	< 0.0001	0.11
Sustained Juiciness[1]	4.71	4.56	0.25	5.01	4.26	< 0.0001	0.10
Initial Tenderness[2]	5.17	5.41	0.66	5.58	5.00	0.28	0.55
Overall Tenderness[2]	5.11	4.90	0.08	5.55	4.47	< 0.0001	0.34
Connective Tissue[3]	5.08	4.99	0.43	5.48	4.60	< 0.0001	0.42
Beef Flavor[4]	2.48	2.29	0.002	2.07	2.71	< 0.0001	0.04
Painty/Fishy Flavor[4]	1.06	1.08	0.39	1.03	1.10	0.003	0.02
Livery/Metallic[4]	1.06	1.04	0.36	1.03	1.07	0.01	0.01

[1] 1 = Extremely dry; 8 = Extremely Juicy
[2] 1 = Extremely tough; 8 = Extremely Tender
[3] 1 = Abundant; 8 = None
[4] 1 = Not detectable; 3 = Strong

As expected, tenderness decreased in steaks from animals supplemented with ZH. This is similar to many studies where ZH supplementation has resulted in increased WBS values as well as reduced consumer scores for tenderness in strip loin steaks (Brooks and Miller, 2009; Shook et al., 2009). Moreover, in the present study, ZH had limited impact on flavor intensity scores which is in contrast to earlier findings where it was reported that ZH can decrease or tends to decrease flavor intensity scores in beef strip loin steaks (Leheska et al., 2009). However, Hilton et al. (2009) reported that consumer acceptability was not negatively impacted by ZH. Zilpaterol is known to cause muscle hypertrophy which correlates to an increase in the diameter of muscle fibers (Mills, 2002). This increase in muscle fiber diameter can lead to a subsequent decrease in tenderness from both an objective and subjective standpoint. Additionally, the improvements in tenderness seen when steaks were enhanced is similar to results shown by Robbins et al. (2002) where both objective and subjective tenderness measurements indicated that enhancement improved the tenderness of beef steaks and roasts and also reported that enhanced round roasts were rated as being more juicy, saltier, and less metallic than non-enhanced roasts.

In conclusion, ZH, when fed for the last 20 d of the finishing phase at 8.3 mg/kg (DM basis), had a positive impact on carcass cutability in calf-fed Holstein steers. Furthermore, ZH supplementation during the final portion of the finishing phase had a negative impact on tenderness; however, this tenderness difference does not adversely affect the classification (tender or tough) given to each steak. Moreover, this study revealed that enhancement has a positive effect on tenderness. Learning to counteract the negative impacts on tenderness seen when using β-AA will allow the beef industry to take full advantage of the improvements in beef production from utilizing these products in the finishing diets of beef cattle.

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