

Effects of feeding zilpaterol hydrochloride for twenty to forty days on carcass cutability and subprimal yield of calf-fed Holstein steers

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ABSTRACT: Zilpaterol hydrochloride (ZH) is designed to increase carcass leanness, chilled side weight (CSW), and percent saleable yield. The objective of this study was to evaluate the effect of a single dose of ZH on cutability and subprimal yield of calf-fed Holstein steers when fed for increasing durations. Two hundred forty steers were fed 8.3 mg/kg of ZH on a DM basis for 0, 20, 30, or 40 d, with a 3-d withdrawal before slaughter. After slaughter, steers were fabricated into 4 pieces (round, loin/flank, rib/plate, and chuck), packaged in combos, shipped to 2 locations, and further fabricated into subprimal pieces and trim. Trim was collected from each primal and separated into groups based on composition of 90, 80, and 50% lean. Zilpaterol hydrochloride increased ($P = 0.01$) CSW by 6.22 kg and saleable yield by 6.4 kg when included in the diet for 20 d. Furthermore, saleable yield as a percentage of CSW was increased ($P = 0.03$) 1.18 percentage units when included in the diet for 20 d. Steers fed ZH for 20 d had heavier strip loins (4.47 vs. 4.12 kg, $P = 0.02$),

tenderloins (2.75 vs. 2.49 kg, $P = 0.02$), and ribeye rolls (5.74 vs. 5.30 kg, $P = 0.01$) than steers not fed ZH. These advantages are further demonstrated as a percentage of CSW. Strip loins ($P = 0.06$), tenderloins ($P = 0.04$), and ribeye rolls ($P = 0.04$) of ZH-fed steers had a greater percentage of CSW than controls. Zilpaterol hydrochloride also increased the percentage of CSW of the 3 primary components of the round when fed for 20 d. The knuckle was 0.10 percentage units heavier ($P = 0.11$), the top round was 0.24 percentage units heavier ($P = 0.04$), and the bottom round was 0.22 percentage units heavier ($P = 0.03$) in ZH-fed steers when compared with steers not fed ZH. Based on these data, it can be concluded that ZH significantly increased subprimal cutting weights, yields, and percentage saleable yield of calf-fed Holstein steers when fed for at least 20 d before slaughter. Zilpaterol hydrochloride increased percentage of CSW of subprimal cuts from Holstein steers in the round and to a lesser degree in the loin.

Key words: β -agonist, cutting yield, Holstein, steer, Zilmax, zilpaterol hydrochloride

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INTRODUCTION

In 2008, the US beef industry slaughtered over 27 million steers and heifers (USDA, 2008). Average BW of slaughtered cattle was 582.9 kg, and dressed 60%

of carcass weight was 352.9 kg (USDA, 2008). Steers had an average carcass weight of 380.6 kg (USDA, 2008) Approximately 10% of slaughtered cattle were Holstein steers (Schaefer, 2005; Smith et al., 2006), which equates to nearly 3 million dairy steers being slaughtered annually in the United States. Holstein steers have decreased cut yields, dressing percentages, and muscle scores compared with beef steers, but palatability characteristics are generally comparable (Knapp et al., 1989). In a review by Rust and Abney (2005),

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Table 1. Number of carcasses selected per treatment based on yield grade

Yield grade (YG)	Days fed ZH ¹			
	0	20	30	40
University of Illinois				
YG1	2	7	13	10
YG2	23	20	18	17
YG3	7	1	0	1
Oklahoma State University				
YG1	1	2	6	3
YG2	13	15	13	11
YG3	15	12	10	13
YG4	1	1	1	3

¹ZH = zilpaterol hydrochloride (Zilmax, Intervet Inc., Millsboro, DE).

tenderness and juiciness of Holstein steers were comparable or more favorable than other beef breeds.

Various metabolic modifiers such as implants, feed additives, and injections have been used to increase ADG, improve feed efficiency, and maximize muscle growth (Dikeman, 2007). One such feed additive, β -agonists, generally causes an increase in protein synthesis, a decrease protein degradation, or some combination of both (Mersmann, 1998). Beta-agonists can decrease lipogenesis and increase lipolysis (McNeel and Mersmann, 1995; Dunshea et al., 2005). The addition of β -agonists in ruminant diets slows the rate of fat accumulation, which causes animals to be leaner (Dunshea et al., 2005). The β_2 -agonists tend to slow protein degradation more than they affect protein synthesis, allowing an increase in protein accumulation. Zilpaterol hydrochloride (ZH) is a β_2 -adrenergic agonist designed to increase BW gain, improve feed efficiency, and increase carcass leanness (FDA, 2006). Increases were reported in carcass weight, dressing percentage, rib-eye area, and 12th-rib thickness in cattle fed ZH when compared with cattle that have not been fed ZH (Plascencia et al., 1999; Vasconcelos et al., 2008). An increase of boneless closely trimmed primal cuts and boneless trimmed retail cuts was reported (Plascencia et al., 1999). Several studies have investigated the effect of ZH on beef cattle, but this is the one of the first in Holstein steers. Therefore, the objective of this study was to evaluate the effect of a single dose of ZH on cutability and subprimal yield of calf-fed Holstein steers when fed for increasing durations.

MATERIALS AND METHODS

No approval was obtained from the University of Illinois Institutional Animal Care and Use Committee for the carcass phase of the experiment because no animals were used in the experiment. Samples were obtained from a federally inspected slaughtering facility. Institutional Animal Care and Use Committee approval was obtained from the respective institutions for the live phase portion of the experiment.

Animals

Blocking, penning, and animal selection during the live phase portion of the experiment are described by Beckett et al. (2009). Steers used in the carcass phase of the experiment were acquired from 2 separate trials. The first was conducted in 2 phases from 4 different sources (2 sources/phase) at a large commercial feed yard with approximately 2,300 steers. The second trial included 359 steers and was conducted in small pens at a university feed yard. Both feeding trials were conducted in the desert southwest of the United States. Steers were fed 8.3 mg/kg of ZH (Zilmax, Intervet Inc., Millsboro, DE) on a DM basis for 0, 20, 30, or 40 d. Zilpaterol hydrochloride was removed from the diet 3 d before slaughter as required by the label. At the end of the 2 feeding trials, cattle were slaughtered according to standard USDA guidelines (USDA, 2005) over 2 d. Carcasses were selected based on treatment weight and calculated yield grade. Initial selection criteria were based on steers that were ± 1 SD from the mean HCW of a pen. Next, selection criteria were set to randomly select 5 yield grade 1, 10 yield grade 2, 11 yield grade 3, and 4 yield grade 4 carcasses per treatment group. However, due to limitations of actual yield grades of the carcasses, obtained yield grade distribution is presented in Table 1. This selection arrangement was conducted in duplicate where 1 set of 119 carcasses were shipped to the University of Illinois Meat Science Lab, Urbana, and a second set of 120 carcasses was shipped to the Food and Agriculture Products Research and Technology Center at Oklahoma State University, Stillwater.

Carcass Fabrication

After an approximate 40-h chilling period steers were fabricated into the following primal cuts: round (NAMP #158), loin (NAMP #172)/flank (NAMP #193), rib (NAMP #103)/plate (NAMP #121), and chuck (NAMP #113; National Association of Meat Purveyors, 2007). One hundred nineteen loins, ribs, and chucks were packaged in combos and shipped via refrigerated trailer to the University of Illinois, Urbana. An additional set of

rounds, loins, ribs, and chucks were packaged in combos and shipped to Oklahoma State University, Stillwater. Upon arrival at their destinations, all 4 primals were weighed and summed by animal identification number for chilled side weights (CSW) and were further fabricated into subprimals trimmed to approximately 6 mm of outside trim. For each primal an intact weight was collected before further fabrication. Salable yield was calculated for each animal by subtracting KPH, fat, and bone from the CSW.

Primal Fabrication

The round was broken into the knuckle (NAMP #167A), inside round (NAMP #168C), bottom round flat (NAMP #171B), eye of the round (NAMP #171C), heel meat (NAMP #171F), and boneless shank meat. Each subprimal, bone, fat, and trim was weighed individually. Trim was separated to a composition of approximately 80% lean.

The loin/flank was broken into the strip loin (NAMP #180C), top sirloin butt (NAMP #184C), bottom sirloin flap (NAMP #185A), bottom sirloin ball tip (NAMP #185B), bottom sirloin tri-tip (NAMP #185D), and peeled tenderloin, side muscle on (NAMP #189D). The flank steak (NAMP # 193) was also removed. Each subprimal including the flank steak, bone, fat, and KPH were weighed individually. Trim was separated into groups based on composition of 50% lean or 80% lean. Each group of trim was weighed individually.

The rib/plate was broken into the ribeye roll (NAMP #112A), back ribs (NAMP #124), rib blade meat (NAMP #109B), export plate (NAMP #121), inside skirt (NAMP #121D), outside skirt (NAMP #121C), and hanging tender (NAMP #140). Each subprimal, bone, and fat was weighed individually. Trim was separated into groups based on composition of 50% lean, 80% lean, or 90% lean. Each group of trim was weighed individually.

The chuck was broken into the shoulder clod (NAMP #114C), shoulder tender (NAMP #114F), chuck eye roll (modified NAMP #116D, arm portion removed 0 mm ventral from the LM at the rib end and not more than 2.54 cm from complexus at the neck end), mock tender (NAMP #116B), short rib (NAMP #130A), pectoral meat (NAMP #115D), whole brisket (NAMP #120), elephant ear (cutaneous trunci), and boneless shank meat. Each subprimal, bone, and fat was weighed individually. Trim was separated into groups based on composition of 50% lean, 80% lean, or 90% lean. Each group of trim was weighed individually. During the primal fabrication period trim was divided into 3 categories: 50/50 trim, 80/20 trim, and 90/10 trim.

Trim Proximate Analysis

After a weight of each trim classification level was recorded, all trim was combined and ground to es-

timate fat, protein, and moisture content. Trim was combined into 1 group to determine protein accumulation and fat reduction differences of whole carcasses between treatment groups. Trim from the fabricated carcasses (90/10, 80/20, and 50/50) was placed into a mixer/grinder, mixed for 5 min, and ground through a 9.5-mm plate to achieve a coarse grind. The coarse ground tissue was then placed back into the mixer and mixed for an additional 5-min period; the soft tissue was then ground through a 4.7-mm plate. After grinding, five 5-cm cores were removed from the ground beef, packaged in whirl-pack bags, and frozen at -20°C until further analysis. Samples were thawed at 0 to 4°C for 24 h. After thawing, samples were powder homogenized using a blender (model 51BL31, Waring, Torrington, CT). Soft tissue moisture, protein, and fat were determined in triplicate according to AOAC (1990) techniques.

Statistical Analysis

Initially, trial and treatment interactions were tested using the GLM procedures (SAS Inst. Inc., Cary, NC). Significant trial \times treatment interactions were noted for various fabrication cut statistics. Evaluation of simple main effects for treatments across trials demonstrated strong differences ($P < 0.001$) for all statistics of interest with significant trial \times treatment interactions. These responses coupled with visual appraisal of response surface data indicated that the interactions were primarily due to magnitude differences for individual treatments across trials. As such, trial data were analyzed as a 2-way classification with replication using the MIXED procedure in SAS. The model statement included treatment, and the random statement included trial and trial \times treatment. Preplanned contrasts were used to test 1) the pairwise comparison of 0 vs. 20 d of ZH feeding; 2) 0 vs. the average of 20, 30, and 40 d of ZH feeding; and 3) the linear effects of days fed ZH. These comparisons were selected to 1) determine if there is a treatment effect at the least inclusion level; 2) to determine if there is a treatment effect across all inclusion levels; and 3) to determine if there is a linear effect of the treatment (ZH) when included for longer durations. For all statistics of interest, model assumptions were tested to ensure variance components were analyzed appropriately. Heteroskedasticity was tested with a null model likelihood ratio test by treating all variance components as fixed effects and identifying treatment with the repeated/group option of PROC MIXED. For cases of heteroskedasticity ($P < 0.15$) the largest SE value is reported. Univariate procedures were used to test normality of model residuals using a Shapiro-Wilks test. In cases of nonnormal distributions ($P < 0.15$), the data were rank transformed, analyzed by the same model as for nontransformed data, and compared against the original data to determine the most conservative probability values.

Table 2. Effect of feeding zilpaterol hydrochloride (ZH) for 20 to 40 d on carcass fabrication values of calf-fed Holstein steers

Item	Days fed ZH				SEM ¹	P-value ²		
	0	20	30	40		0 vs. 20	0 vs. others	Linear
Chilled side weight, kg	185.18	191.40	191.84	192.95	11.71	0.01	<0.01	0.25
Elephant ear, kg	1.35	1.41	1.56	1.50	0.14	0.54	0.05	0.21
% of chilled carcass wt	0.73	0.74	0.81	0.78	0.03	0.99	0.13	0.23
50/50 trim, kg	14.35	14.01	13.99	13.78	6.32	0.78	0.52	0.65
% of chilled carcass wt	7.55	7.13	7.12	6.96	2.87	0.25	0.10	0.50
80/20 trim, kg	13.54	13.93	13.67	14.80	4.35	0.49	0.23	0.18
% of chilled carcass wt	7.49	7.46	7.31	7.83	2.75	0.94	0.83	0.25
90/10 trim, kg	6.87	7.39	7.72	6.99	2.42	0.85	0.51	0.88
% of chilled carcass wt	3.66	3.78	3.95	3.56	1.04	0.71	0.91	0.81
Kidney knob fat, kg	6.37	6.61	6.18	6.62	0.95	0.48	0.71	0.98
% of chilled carcass wt	3.34	3.44	3.20	3.41	0.30	0.97	0.58	0.90
Fat trim, kg	13.88	13.26	13.20	13.62	0.79	0.30	0.29	0.62
% of chilled carcass wt	7.54	6.99	6.94	7.11	0.83	0.11	0.07	0.67
Bone, kg	40.25	40.33	40.19	39.81	1.15	0.83	0.66	0.24
% of chilled carcass wt	21.77	21.13	20.99	20.69	0.71	0.04	0.01	0.09
Saleable yield, kg	124.77	131.17	132.28	132.89	10.37	0.01	<0.01	0.20
% of chilled carcass wt	67.26	68.44	68.87	68.79	1.25	0.03	0.01	0.32

¹Pooled SE of treatment means; within a trial n = 28 to 32 carcasses/treatment. Because of the slightly unbalanced numbers among treatments and heteroskedasticity in some cases, the largest SE is reported.

²Observed significance level for contrasts: 0 vs. 20 = pairwise comparison of 0 vs. 20 d ZH (Zilmax, Intervet Inc., Millsboro, DE) feeding; 0 vs. others = d 0 vs. the average of 20, 30, and 40 d of Zilmax feeding; linear = linear effects of days fed ZH.

RESULTS AND DISCUSSION

Carcass

Zilpaterol hydrochloride was effective in increasing CSW and saleable yield when included in the diet of calf-fed Holstein steers for at least 20 d before slaughter (Table 2). There was an increase in CSW ($P = 0.01$) of 6.22 kg when ZH was included in the diet for up to 20 d when compared with steers that were not fed ZH. Chilled side weight increased ($P < 0.01$) 7.77 kg when ZH was included in the diet for up to 40 d when compared with steers that were not fed ZH. Saleable yield increased ($P = 0.01$) 6.40 kg when ZH was included in the diet for up to 20 d when compared with steers that were not fed ZH. Saleable yield increased ($P < 0.01$) 8.12 kg when ZH was included in the diet for up to 40 d when compared with steers that were not fed ZH. This increase in saleable yield represents a 1.18% increase in percent CSW when ZH is fed for 20 d and a 1.53% increase in percent CSW when ZH is fed for 40 d. This is similar to results found in Avendano-Reyes et al. (2006) that included 45 beef type steers where ZH was fed 30 d. In that study ZH-fed steers had heavier CSW, increased HCW, increased dressing percentage, and increased LM area. For steers not fed ZH, saleable yield was 67% of CSW (Table 2). Average BW of steers and heifers slaughtered under federal inspection in the United States in 2006 was 580 kg (Meat and Poultry Facts, 2007) with an average dressed weight of those steers and heifers being 355 kg (Meat and Poultry Facts, 2007). With an average of 3 million dairy steers slaughtered each year yielding 67% saleable product, total pounds of saleable product would increase from

approximately 714 million to 724 million kg if all of those steers were fed ZH for at least 20 d.

Protein to bone ratio was improved in beef steers and heifers fed ZH for 20 or 40 d (Leheska et al., 2009). Similar results were found in this study. Numerical protein to bone ratio was improved from 0.61 to 0.67 when steers were fed ZH for 20 d. When evaluated on a saleable yield to bone ratio, steers fed ZH for 20 d have a saleable yield to bone ratio of 3.25 and the control steers saleable yield to bone ratio is only 3.1 (Table 2).

Round

Zilpaterol hydrochloride tended to have the greatest impact on increase of percent CSW in the round. The knuckle ($P = 0.02$), top round ($P = 0.01$), bottom round ($P = 0.01$), eye of round ($P = 0.04$), and heel meat ($P = 0.03$) were all significantly heavier in steers that were fed ZH for at least 20 d when compared with steers that were not fed ZH (Table 3). Steers that were fed ZH for 20, 30, or 40 d also had heavier knuckles ($P = 0.01$), top rounds ($P < 0.01$), bottom rounds ($P = 0.01$), eye of round ($P < 0.01$), and heel meat ($P = 0.01$) than steers that were not fed ZH (Table 3). The knuckle, top round, and bottom round make up 11.47% of the CSW of steers not fed ZH. The knuckle, top round, and bottom round make up 12.03% of the CSW of steers fed ZH for 20 d. The knuckle, top round, and bottom round make up 12.17% of the chilled carcass weight of steers fed ZH for up to 40 d. These results agree with Hilton et al. (2009) where ZH had a greater impact on the hind quarter more than other parts of the carcass. The knuckle, top round, and bottom round from ZH fed to beef steers made up 13.26% of CSW

Table 3. Effect of feeding zilpaterol hydrochloride (ZH) for 20 to 40 d on round primal values of calf-fed Holstein steers

Item	Days fed ZH				SEM ¹	P-value ²		
	0	20	30	40		0 vs. 20	0 vs. others	Linear
Knuckle (peeled), kg	5.14	5.50	5.57	5.68	0.28	0.02	0.01	0.13
% of chilled carcass wt	2.78	2.88	2.91	2.95	0.04	0.11	0.04	0.24
Top (inside) round, kg	9.83	10.62	10.68	10.75	0.42	0.01	<0.01	0.41
% of chilled carcass wt	5.32	5.56	5.57	5.58	0.13	0.04	0.02	0.71
Bottom round (flat), kg	6.25	6.87	7.03	7.02	0.46	0.01	0.01	0.37
% of chilled carcass wt	3.37	3.59	3.66	3.64	0.04	0.03	0.01	0.57
Eye of round, kg	2.54	2.77	2.83	2.93	0.04	0.02	<0.01	0.05
% of chilled carcass wt	1.38	1.45	1.48	1.52	0.08	0.06	0.01	0.07
Heel meat, kg	2.27	2.42	2.48	2.53	0.03	0.03	0.01	0.06
% of chilled carcass wt	1.23	1.27	1.30	1.32	0.08	0.11	0.02	0.09

¹Pooled SE of treatment means; within a trial n = 28 to 32 carcasses/treatment. Because of the slightly unbalanced numbers among treatments and heteroskedasticity in some cases, the largest SE is reported.

²Observed significance level for contrasts: 0 vs. 20 = pairwise comparison of 0 vs. 20 d ZH (Zilmax, Intervet Inc., Millsboro, DE) feeding; 0 vs. others = d 0 vs. the average of 20, 30, and 40 d of ZH feeding; linear = linear effects of days fed ZH.

and control knuckles, top rounds, and bottom rounds made up only 12.11% of CSW (Hilton et al., 2009).

Loin/Flank

Zilpaterol hydrochloride also had an effect on the loin/flank as a percentage of CSW, but to a lesser degree than in the round. Even so, most subprimal cuts were heavier in ZH-fed steers than in control steers. The strip loin ($P = 0.02$), top sirloin butt ($P = 0.03$), bottom sirloin tri-tip ($P = 0.03$), and peeled tenderloin ($P = 0.02$) were all significantly heavier in steers that were fed ZH for at least 20 d when compared with steers that were not fed ZH (Table 4). The strip loin ($P = 0.01$), top sirloin butt ($P = 0.01$), bottom sirloin tri-tip ($P = 0.01$), and peeled tenderloin ($P = 0.01$) were all significantly heavier in steers that were fed

ZH for 20, 30, or 40 d when compared with steers that were not fed ZH (Table 4). The strip loin (4.47 kg) of steers fed ZH for 20 d was 0.35 kg heavier ($P = 0.02$) than the strip loin of steers not fed ZH (4.12 kg). The top sirloin butt (5.86 kg) of steers fed ZH for 20 d was 0.33 kg heavier ($P = 0.03$) than the top sirloin butt of steers not fed ZH (5.53 kg). The peeled tenderloin ($P = 0.04$) and strip loin ($P = 0.06$) made up a larger portion of percentage of CSW in ZH-fed steers than in control steers. The loin/flank portion of the carcass made up 0.35 percentage units more of the chilled side weight for the carcasses from steers fed ZH for 20 d (8.77% of CSW) when compared with steers not fed ZH (8.42% of CSW). The loin/flank portion of the carcass made up 0.46 percentage units more of the CSW for the carcasses from steers fed ZH for up to 40 d (8.88% of CSW) when compared with steers not fed ZH

Table 4. Effect of feeding zilpaterol hydrochloride (ZH) for 20 to 40 d on loin and flank primal values of calf-fed Holstein steers

Item	Days fed ZH				SEM ¹	P-value ²		
	0	20	30	40		0 vs. 20	0 vs. others	Linear
Strip loin (0 × 1), kg	4.12	4.47	4.55	4.63	0.37	0.02	0.01	0.15
% of chilled carcass wt	2.22	2.33	2.37	2.40	0.06	0.06	0.02	0.20
Top sirloin butt, kg	5.53	5.86	5.99	5.90	0.44	0.03	0.01	0.67
% of chilled carcass wt	2.98	3.06	3.12	3.06	0.05	0.17	0.07	0.94
Bottom sirloin flap (denuded), kg	1.04	1.07	1.12	1.13	0.56	0.50	0.12	0.22
% of chilled carcass wt	0.55	0.55	0.57	0.57	0.26	0.99	0.40	0.29
Bottom sirloin ball tip (denuded), kg	0.57	0.62	0.67	0.61	0.05	0.31	0.16	0.85
% of chilled carcass wt	0.31	0.32	0.35	0.32	0.02	0.49	0.26	0.23
Bottom sirloin tri-tip (denuded), kg	1.00	1.10	1.14	1.14	0.03	0.03	0.01	0.25
% of chilled carcass wt	0.54	0.58	0.60	0.60	0.02	0.08	0.02	0.32
Peeled tender, side muscle on (denuded), kg	2.49	2.75	2.81	2.80	0.28	0.02	0.01	0.49
% of chilled carcass wt	1.34	1.44	1.46	1.45	0.06	0.04	0.02	0.68
Flank steak, kg	0.89	0.94	0.97	0.93	0.09	0.26	0.14	0.93
% of chilled carcass wt	0.48	0.49	0.50	0.48	0.02	0.65	0.47	0.79

¹Pooled SE of treatment means; within a trial n = 28 to 32 carcasses/treatment. Because of the slightly unbalanced numbers among treatments and heteroskedasticity in some cases, the largest SE is reported.

²Observed significance level for contrasts: 0 vs. 20 = pairwise comparison of 0 vs. 20 d ZH (Zilmax, Intervet Inc., Millsboro, DE) feeding; 0 vs. others = d 0 vs. the average of 20, 30, and 40 d of ZH feeding; linear = linear effects of days fed ZH.

Table 5. Effect of feeding zilpaterol hydrochloride (ZH) for 20 to 40 d on rib and plate primal values of calf-fed Holstein steers

Item	Days fed ZH				SEM ¹	P-value ²		
	0	20	30	40		0 vs. 20	0 vs. others	Linear
Ribeye roll, lip on (2 × 2), kg	5.30	5.74	5.73	5.74	0.25	0.01	0.01	0.98
% of chilled carcass wt	2.87	3.00	2.99	2.98	0.06	0.04	0.03	0.59
Rib back ribs, kg	1.86	1.90	1.89	1.95	0.30	0.42	0.22	0.33
% of chilled carcass wt	1.02	1.01	1.00	1.02	0.22	0.53	0.51	0.58
Rib blade meat, kg	1.31	1.50	1.46	1.49	0.18	0.04	0.03	0.92
% of chilled carcass wt	0.71	0.78	0.76	0.77	0.05	0.07	0.05	0.72
Export plate, kg	7.78	7.99	8.01	8.04	1.65	0.37	0.24	0.80
% of chilled carcass wt	4.27	4.24	4.25	4.23	1.13	0.73	0.68	0.96
Inside skirt, kg	1.21	1.23	1.30	1.29	0.08	0.62	0.12	0.20
% of chilled carcass wt	0.66	0.65	0.68	0.67	0.08	0.52	0.63	0.24
Outside skirt (peeled), kg	0.64	0.68	0.68	0.68	0.04	0.27	0.17	0.92
% of chilled carcass wt	0.35	0.35	0.36	0.35	0.01	0.94	0.97	0.94

¹Pooled SE of treatment means; within a trial n = 28 to 32 carcasses/treatment. Because of the slightly unbalanced numbers among treatments and heteroskedasticity in some cases, the largest SE is reported.

²Observed significance level for contrasts: 0 vs. 20 = pairwise comparison of 0 vs. 20 d ZH (Zilmax, Intervet Inc., Millsboro, DE) feeding; 0 vs. others = d 0 vs. the average of 20, 30, and 40 d of ZH feeding; linear = linear effects of days fed ZH.

(8.42% of CSW). Hilton et al. (2009) reported similar differences in beef steers where the loin/flank of ZH fed cattle made up 11.95% of CSW, whereas the loin/flank of control cattle made up only 11.04% of CSW.

Rib/Plate

The rib eye roll ($P = 0.01$) and blade meat ($P = 0.03$) were both significantly heavier in steers that were fed ZH for 20, 30, or 40 d when compared with steers that were not fed ZH (Table 5). The back ribs, export plate, inside skirt, and outside skirt were not different ($P > 0.05$) in steers fed ZH for 20, 30, or 40 d when compared with steers that were not fed ZH.

The rib eye roll of steers fed ZH for 20 d (5.74 kg) was 0.44 kg heavier ($P = 0.01$) than the rib eye roll of steers that were not fed ZH (5.30 kg). The rib eye roll of steers fed ZH for up to 40 d (5.74 kg) was 0.44 kg heavier ($P = 0.01$) than the rib eye roll of steers that were not fed ZH (5.30 kg). Even though the weights of individual cuts of ZH-fed steers were heavier, there was little impact of ZH in terms of cuts as a percentage of CSW (Table 5).

Chuck

The shoulder clod ($P = 0.01$) and shank meat ($P = 0.01$) were heavier in steers that were fed ZH for 20,

Table 6. Effect of feeding zilpaterol hydrochloride (ZH) for 20 to 40 d on chuck primal values of calf-fed Holstein steers

Item	Days fed ZH				SEM ¹	P-value ²		
	0	20	30	40		0 vs. 20	0 vs. others	Linear
Chuck shoulder clod, trimmed, kg	8.07	8.57	8.61	8.64	1.94	0.02	0.01	0.56
% of chilled carcass wt	4.31	4.43	4.44	4.43	0.75	0.11	0.06	0.95
Chuck shoulder tender, kg	0.46	0.50	0.49	0.48	0.36	0.16	0.17	0.57
% of chilled carcass wt	0.25	0.26	0.25	0.25	0.01	0.38	0.56	0.46
Chuck eye roll, kg	7.76	8.21	8.13	8.02	0.86	0.08	0.08	0.34
% of chilled carcass wt	4.18	4.28	4.22	4.14	0.19	0.32	0.87	0.85
Chuck (mock) tender, trimmed to blue, kg	1.62	1.71	1.67	1.69	0.27	0.06	0.07	0.53
% of chilled carcass wt	0.87	0.89	0.86	0.87	9.72	0.27	0.66	0.34
Chuck short rib, boneless, kg	1.34	1.28	1.37	1.31	0.11	0.34	0.69	0.64
% of chilled carcass wt	0.72	0.67	0.71	0.68	0.02	0.13	0.18	0.81
Pectoral meat (trimmed to blue), kg	0.71	0.78	0.79	0.75	0.90	0.14	0.12	0.52
% of chilled carcass wt	0.38	0.41	0.41	0.39	0.02	0.23	0.23	0.42
Brisket, whole boneless (packer trim), kg	5.89	6.04	6.15	6.27	0.33	0.33	0.09	0.18
% of chilled carcass wt	3.18	3.15	3.21	3.25	0.05	0.69	0.68	0.23
Boneless shank meat, kg	2.45	2.57	2.59	2.66	0.21	0.04	0.01	0.11
% of chilled carcass wt	1.32	1.34	1.35	1.38	0.03	0.31	0.09	0.17

¹Pooled SE of treatment means; within a trial n = 28 to 32 carcasses/treatment. Because of the slightly unbalanced numbers among treatments and heteroskedasticity in some cases, the largest SE is reported.

²Observed significance level for contrasts: 0 vs. 20 = pairwise comparison of 0 vs. 20 d ZH (Zilmax, Intervet Inc., Millsboro, DE) feeding; 0 vs. others = d 0 vs. the average of 20, 30, and 40 d of ZH feeding; linear = linear effects of days fed ZH.

Table 7. Effect of feeding zilpaterol hydrochloride (ZH) for 20 to 40 d on carcass composition values of calf-fed Holstein steers

Item	Days fed ZH				SEM ¹	P-value ²		
	0	20	30	40		0 vs. 20	0 vs. others	Linear
Moisture, %	51.63	53.29	53.10	52.93	0.57	0.04	0.03	0.99
Protein, %	13.29	14.15	14.02	14.44	0.22	0.01	<0.001	0.35
Fat, %	33.78	31.24	31.79	31.27	0.82	0.03	0.02	0.60

¹Pooled SE of treatment means; within a trial n = 28 to 32 carcasses/treatment. Because of the slightly unbalanced numbers among treatments and heteroskedasticity in some cases, the largest SE is reported.

²Observed significance level for contrasts: 0 vs. 20 = pairwise comparison of 0 vs. 20 d ZH (Zilmax, Intervet Inc., Millsboro, DE) feeding; 0 vs. others = d 0 vs. the average of 20, 30, and 40 d of ZH feeding; linear = linear effects of days fed ZH.

30, or 40 d when compared with steers that were not fed ZH (Table 6). The chuck eye roll ($P = 0.08$), chuck (mock) tender ($P = 0.07$), and whole boneless brisket ($P = 0.09$) were all heavier in steers that were fed ZH for steers fed 20, 30, or 40 d when compared with steers that were not fed ZH (Table 6). There were no differences in weight ($P > 0.05$) in chuck shoulder tender, short ribs, or pectoral meat in steers fed ZH for 20, 30, or 40 d when compared with steers that were not fed ZH.

Trim

There were no differences in weight ($P > 0.05$) of 50% lean trim, 80% trim, 90% trim, total fat trim, KPH fat, or bone in steers fed ZH when compared with steers that were not fed ZH (Table 2).

Trim Proximate Analysis

As expected the inclusion of ZH successfully increased trim percent protein and reduced trim percent fat. Past reports in pork (Dunshea et al., 1993) and beef (Hilton et al., 2009) have reported carcass composition changes when β -agonists are included in the diet during the finishing phases of production. Steers fed ZH for 20 d (14.15%) had greater protein percentages ($P = 0.01$) than steers not fed ZH (13.29%; Table 7). Steers fed ZH for 20, 30, or 40 d had greater protein percentages ($P < 0.001$) than steers not fed ZH. Steers fed ZH for 20 d (31.24%) had less fat percentages ($P = 0.03$) than steers not fed ZH (33.78). Steers fed ZH for 20, 30, or 40 d had less fat percentages ($P = 0.02$) than steers not fed ZH. These results are similar to Leheska et al. (2009) where they reported an increase in percent protein, but percent fat was not affected by ZH inclusion. Hilton et al. (2009) reported increases in percent carcass protein and decreases in percent carcass fat when ZH was fed for the last 30 d of finishing. Steers fed ZH for 20 d (53.29%) had greater moisture percentages ($P = 0.04$) than steers not fed ZH (51.63%; Table 7). Steers fed ZH for 20, 30, or 40 d had greater moisture percentages ($P = 0.03$) than steers not fed ZH. Whereas Leheska et al. (2009) reported a numerical increase in percent moisture of ZH steers fed for 20 d, the magnitude of the

difference were less (0.83) than this experiment (1.66). Even so, Hilton et al. (2009) reported increases in percent moisture of steers fed ZH independent of monensin/tylosin inclusion vs. control steers.

Conclusion

Zilpaterol hydrochloride significantly increased subprimal weights and cutting yields in the round, loin/flank, rib/plate, and chuck of calf-fed Holstein steers when fed for at least 20 d before slaughter. However, ZH had the largest impact on increasing percentage of CSW in the round when compared with any other primal in the carcass. The loin/flank was also increased as a percentage of CSW, but to a lesser degree. The increase in subprimal weights led to a greater percentage of saleable yield. This provides producers the opportunity to market more kilograms of lean product. Increased saleable yields translate into a greater probability to profit.

LITERATURE CITED

- AOAC. 1990. Official Methods of Analysis. 15th ed. Assoc. Off. Anal. Chem., Arlington, VA.
- Avendano-Reyes, L., V. Torres-Rodriguez, F. J. Meraz-Murillo, C. Perez-Linares, F. Figueroa-Saavedra, and P. H. Robinson. 2006. Effects of two β -adrenergic agonists on finishing performance, carcass characteristics, and meat quality of feedlot steers. *J. Anim. Sci.* 84:3259-3265.
- Beckett, J. L., R. J. Delmore, G. Duff, D. A. Yates, D. M. Allen, N. A. Elam, and T. E. Lawrence. 2009. Effects of zilpaterol hydrochloride on growth rates, feed conversion and carcass traits in calf-fed Holstein steers. *J. Anim. Sci.* doi:10.2527/jas.2009-1808
- Dikeman, M. E. 2007. Effects of metabolic modifiers on carcass traits and meat quality. *Meat Sci.* 77:121-135.
- Dunshea, F. R., D. N. D'Souza, D. W. Pethick, G. S. Harper, and R. D. Warner. 2005. Effects of dietary factors and other metabolic modifiers on quality and nutritional value of meat. *Meat Sci.* 71:8-38.
- Dunshea, F. R., R. H. King, R. G. Campbell, R. D. Sainz, and Y. S. Kim. 1993. Interrelationships between sex and ractopamine on protein and lipid deposition in rapidly growing pigs. *J. Anim. Sci.* 71:2919-2930.
- FDA. 2006. Freedom of Information Summary. Original New Animal Drug Application NADA 141-258. Zilmax (Zilpaterol Hydrochloride). Type A Medicated Article for Cattle Fed in Confinement for Slaughter. <http://www.fda.gov/cvm/FOI/141-258o08102006.pdf> Accessed Mar. 26, 2009.

- Hilton, G. G., J. L. Montgomery, C. R. Krehbiel, D. A. Yates, J. P. Hutcheson, W. T. Nichols, M. N. Streeter, J. R. Blanton Jr., and M. F. Miller. 2009. Effects of feeding zilpaterol hydrochloride with and without monensin and tylosin on carcass cutability and meat palatability of beef steers. *J. Anim. Sci.* 87:1394–1406.
- Knapp, R. H., C. A. Terry, J. W. Savell, H. R. Cross, W. L. Mies, and J. W. Edwards. 1989. Characterization of cattle types to meet specific targets. *J. Anim. Sci.* 67:2294–2308.
- Leheska, J. M., J. L. Montgomery, C. R. Krehbiel, D. A. Yates, J. P. Hutcheson, W. T. Nichols, M. Streeter, J. R. Blanton, and M. F. Miller. 2009. Dietary zilpaterol hydrochloride. II. Carcass composition and meat palatability of beef cattle. *J. Anim. Sci.* 87:1384–1393.
- McNeel, R. L., and H. J. Mersmann. 1995. Beta-adrenergic receptor subtype transcripts in porcine adipose tissue. *J. Anim. Sci.* 73:1962–1971.
- Meat and Poultry Facts. 2007. Am. Meat Inst., Washington, DC.
- Mersmann, H. J. 1998. Overview of the effects of β -adrenergic receptor agonists on animal growth including mechanisms of action. *J. Anim. Sci.* 76:160–172.
- NAMP. 2007. The Meat Buyer's Guide. North Am. Meat Proc. Assoc., Reston, VA.
- Plascencia, A., N. Torrentera, and R. A. Zinn. 1999. Influence of the beta-agonist, zilpaterol, on growth performance and carcass characteristics of feedlot steers. *Proc. Western Sect Am. Soc. Anim. Sci.* 50:331–334.
- Rust, S. R., and C. S. Abney. 2005. Comparison of dairy versus beef steers. Pages 161–174 in *Managing and Marketing Quality Holstein Steers Conf.* R. Tigner and J. Lehmkuhler, ed. Wis. Agric. Service Assoc., Madison, WI.
- Schaefer, D. M. 2005. Yield and quality of Holstein beef. Pages 323–333 in *Managing and Marketing Quality Holstein Steers Conf.* R. Tigner and J. Lehmkuhler, ed. Wis. Agric. Service Assoc., Madison, WI.
- Smith, G. C., J. W. Savell, J. B. Morgan, and T. E. Lawrence. 2006. Report of the June-September 2005 national beef quality audit: A new benchmark for the U.S. beef industry. <http://www.bifconference.com/bif2006/pdf/Morgan.pdf> Accessed Mar. 28, 2009.
- USDA. 2005. 9 CFR 313—Humane slaughter of livestock. USDA, Washington, DC.
- USDA. 2008. Annual meat trade review: Meat, livestock, & slaughter data. <http://www.ams.usda.gov/mnreports/l sancmtr.pdf> Accessed Mar. 28, 2009.
- Vasconcelos, J. T., R. J. Rathmann, R. R. Reuter, J. Leibovich, J. P. McMeniman, K. E. Hales, T. L. Covey, M. F. Miller, W. T. Nichols, and M. L. Galyean. 2008. Effects of duration of zilpaterol hydrochloride feeding and days on the finishing diet on feedlot cattle performance and carcass traits. *J. Anim. Sci.* 86:2005–2015.