Carcass fabrication yields of beef steers supplemented zilpaterol hydrochloride and offered ad libitum or maintenance energy intake[1]

Angela N. Schmitz,* Lee-Anne J. Walter,* Wade T. Nichols,† John P. Hutcheson,† and Ty E. Lawrence*,[2]

*Beef Carcass Research Center, Department of Agricultural Sciences, West Texas A&M University, Canyon, TX 79016; and †Merck Animal Health, Summit, NJ 07901

ABSTRACT: An experiment was conducted to evaluate the fabrication yields of carcasses from beef steers supplemented zilpaterol hydrochloride (**ZH**) and fed at maintenance (**MA**) or ad libitum (**AB**) intake levels. Beef steers (n = 56) from a common sire were blocked (n = 28 per block) by terminal growth implant and sorted into pairs by BW. Four pairs (n = 8) were harvested on day 0; the remaining 24 pairs (n = 48) were assigned to a dietary intake level (MA or AB) and days on feed (28 or 56 d). Within pairs of MA or AB intakes, steers harvested on day 56 were randomly assigned to supplementation of ZH (90 mg·d^{-1} per steer) for 20 d followed by a withdrawal period of 4 d or control (**C**). Steers (BW = 603.5 ± 48.1 kg) were harvested at a commercial processing facility. After a 24-h chill period, standard USDA grading procedures were used to derive a calculated yield grade and quality grade. Following grading, left carcass sides were transported to the West Texas A&M University Meat Laboratory for fabrication. Each side was fabricated into subprimals to determine individual red meat yield (**RMY**), trimmable fat yield (**TFY**), and bone yield (**BY**). A mixed model was used for analysis; fixed effects included treatment combinations and random effects included block and pairs. Single df contrasts tested day 0 vs. 28, day 0 vs. 56, day 28 vs. 56, MA vs. AB, and C vs. ZH. Yield of chuck eye roll differed (P = 0.05) by days on feed (0 d = 4.14, 28 d = 4.11, 56 d = 4.55%). Similarly, eye of round yield was impacted (P = 0.02) by days on feed (0 d = 1.51, 28 d = 1.37, 56 d = 1.36%). Additionally, brisket yield was altered (P < 0.01) by days on feed (0 d = 4.08, 28 d = 3.56, 56 d = 3.48%) and treatment (C = 3.34, ZH = 3.61%). For remaining subprimals, no differences (P ≥ 0.15) were detected. Furthermore, results indicated that RMY tended (P = 0.07) to differ by treatment (C = 61.35, ZH = 63.67%). Comparatively, TFY was impacted (P = 0.04) by intake (MA = 20.44, AB = 23.33%). Results from this study indicate that a MA intake level during the last 56 d of the finishing period concurrent with ZH supplementation impacts subprimal yields as well as carcass RMY and TFY of beef steers.

Key words: cutability, steers, zilpaterol

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INTRODUCTION

Zilpaterol hydrochloride (**ZH**), a β_2 adrenergic agonist, has been used to improve the efficiency of terminal cattle growth in the cattle feeding industry (Lawrence et al., 2011). Previous research has

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[2] Corresponding Author: tlawrence@wtamu.edu

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reported that ZH enhanced growth performance and red meat yield (**RMY**) in steers and heifers by increasing HCW, dressed carcass yield, and LM area (Montgomery et al., 2009; Garmyn et al., 2010; Rathmann et al., 2012). In addition, ZH has been reported to increase subprimal weights and cutting yields of calf-fed Holstein and native steers when fed during the end of the feeding period (Avendaño-Reyes et al., 2006; Boler et al., 2009, Hilton et al., 2009, 2010; Leheska et al., 2009, Neill et al., 2009; Robles-Estrada et al., 2009; Scramlin et al., 2010). Similarly, Lawrence et al. (2011) reported an improvement in feeding performance carcass yield characteristics and fabrication values of cull cows fed ZH 20 d prior to slaughter.

Zilpaterol hydrochloride is administered during the end of the finishing period in which cattle in commercial settings are typically allowed ad libitum (**AB**) access to feed. However, Murphy and Loerch (1994) observed improvements in feed efficiency concomitant with reduced 12th rib s.c. fat when cattle were restricted to 80% and 90% of AB intake levels. These authors also reported constant daily protein accretion but a linear decrease in lipid accretion when cattle were restricted intake (up to 80% AB intake level).

We are unaware of research pertaining to the fabrication and subprimal yields of beef steers fed at maintenance (**MA**) and supplemented ZH prior to slaughter. Therefore, the objective of this study was to evaluate the fabrication yields of carcasses from beef steers supplemented ZH and fed at MA or AB dietary intake levels.

MATERIALS AND METHODS

The live phase portion of the experiment adhered to all guidelines described in the Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching (Federation of Animal Science Societies, 2010, Savoy, IL) and was approved by the West Texas A&M University Institutional Animal Care and Use Committee (#02-06-14).

Animals

The live phase portion of the experiment, detailing the experimental design, diet and feeding, transportation, harvest and grading of the steers, was previously described in a companion paper (Walter et al., 2018). Briefly, steers (n = 56) were blocked (28 steers per block) by terminal implant (Revalor XS or Revalor S, Merck Animal Health, Summit, NJ) and randomized to pairs by BW. Four pairs (8 steers) were harvested on day 0; the remaining 24 pairs (48 steers) were assigned to MA (24 steers) or AB (24 steers) dietary intake level and 28 (16 steers) or 56 (32 steers) days on feed. Within pairs of MA or AB dietary intake level, steers harvested on day 56 were randomly assigned to control (C) or supplementation of ZH (90 mg·d^{-1} per steer) for 20 d followed by a withdrawal period of 4 d. Thus, treatment combinations included day 0, day 28 MA, day 28 AB, day 56 MAC, day 56 MAZH, day 56 ABC, and day 56 ABZH. All steers were harvested at a commercial beef processor (Caviness Packing Company, Establishment 675; Hereford, TX). Immediately following harvest, HCW and actual KPH weight were recorded for each carcass. Carcasses were allowed a 24-h post-slaughter chill period before each left carcass side was ribbed between the 12th and 13th ribs for standard (USDA, 1997) grading procedures. Following all grading procedures, left carcass sides were transported to the West Texas A&M University Meat Laboratory for further processing.

Carcass Fabrication

Left carcass sides were fabricated into the following primal cuts (48-h post-harvest) according to guidelines of the North American Meat Institute (NAMI, 2014): round (NAMI #158), loin (NAMI #172)/flank (NAMI #193), rib (NAMI #103)/plate (NAMI #121), and chuck (NAMI #113)/brisket (NAMI #120). All primals were weighed individually ±0.01 kg (ABM-60, Universal Weight Enterprise Company, Xindian City, Taiwan) and summed to determine cold carcass side weight (**CSW**); both weights and weights as a percentage of CSW were calculated. The left side of one carcass from a steer assigned to the AB dietary intake level for 28 d on feed had a severely trimmed chuck and thus was not included in these data. Individual primals were then fabricated into trimmed subprimals. Round primals were separated into the knuckle (NAMI #167A), top (inside) round (NAMI #168), bottom (outside) round (NAMI #171B), eye of round (NAMI #171C), heel meat (NAMI # 171F), and boneless shank meat. Loin/flank primals were separated into the strip loin (NAMI #180), top sirloin butt (NAMI #184C), bottom sirloin tri-tip (NAMI #185D), peeled tenderloin, side on (NAMI #189D), and bottom sirloin ball tip (NAMI #185B). Flank steak (NAMI #193) was separated from the fat and bone as well as the bottom sirloin flap (NAMI #185A) and elephant ear. Rib/plate primals were separated into the ribeye roll, lip on (NAMI #112A), back ribs (NAMI #124), rib blade meat (NAMI #109B), inside skirt (NAMI #121D), outside skirt (NAMI #121C), and hanging tender (NAMI #140). Chuck primals were separated into the shoulder clod (NAMI #114), top blade (NAMI #114D), shoulder tender (NAMI #114F), chuck eye roll (NAMI #116D), mock tender (NAMI #116B), short rib (NAMI #130A), pectoral meat (NAMI #115D), whole brisket (NAMI #120), and foreshank (NAMI #117).

Fabricated subprimals were weighed ±0.01 kg (ABM-60, Universal Weight Enterprise Company) individually for each primal, with results shown as weights and as a percentage of CSW. In addition, the bone, fat, and lean trim (visual 80/20) were weighed individually for each primal. After the bone, fat, and lean trim weights were captured for each primal, all bone trim was combined and weighed across primals followed by all fat and lean trim. Weight of the lean trim and subprimals combined was RMY and as a percentage of CSW was RMY%. Weights of all trimmable fat and bones were combined across primals, respectively, and labeled as trimmable fat yield (**TFY**) and bone yield (**BY**) and as a percentage of CSW as TFY% and BY%.

Statistical Analysis

The experiment was developed as a multifactorial design which included three harvest dates, two dietary intake levels and ZH supplementation or control (C) and is discussed in further detail by Walter et al. (2018). Fabrication data were analyzed using the MIXED model procedures (SAS Inst. Inc., Cary, NC). Fixed effects included the treatment combinations and random effects included block and pairs. Each individual carcass side was an experimental unit. Single df contrasts were constructed to test comparisons of day 0 vs. 28, day 0 vs. 56, day 28 vs. 56, MA vs. AB, and control (C) vs. ZH. The KENWARDROGER option was used to generate new denominator degrees of freedom. A LSMEANS statement generated means and a PDIFF statement was used to assess differences due to harvest day or ZH supplementation. Differences were considered significant at a P value of ≤0.05 and trends at a P value of ≤0.10.

RESULTS

Carcass Data

The frequencies of carcass yield and quality grades among the 55 carcasses are represented in Table 1. Throughout the study, carcasses did not exhibit a yield grade lower than 2.0. The calculated yield grade with the greatest frequency was 3.0 to 3.9 followed by yield grade 4.0 to 4.9, 2.0 to 2.9, and finally ≥5.0. Furthermore, the overall quality grades remained within select and choice.

Table 1. Values (relative frequency, %) of carcass yield[1] and quality[2] traits among fifty-five carcasses

Calculated yield grade	Choice	Select	Total
1.0–1.9	—	—	—
2.0–2.9	6 (10.91%)	3 (5.45%)	9 (16.36%)
3.0–3.9	24 (42.63%)	5 (9.09%)	29 (52.72%)
4.0–4.9	10 (18.18%)	2 (3.64%)	12 (21.82%)
≥5.0	3 (5.45%)	2 (3.64%)	5 (9.09%)
Total	43 (78.18%)	12 (21.82%)	55 (100.00%)

[1] Based on USDA Beef Carcass Grading Standards (USDA, 1997); yield grade= 2.5 + (2.50 × adjusted fat thickness, inches) + (0.20 × percent kidney, pelvic, and heart fat) + (0.0038 × HCW, pounds) − (0.32 × area ribeye, square inches).

[2] Based on USDA Beef Carcass Grading Standards (USDA, 1997); quality grades: Select = Slight$^{0\text{–}49}$, Slight$^{50\text{–}100}$ and Choice= Small$^{00\text{–}100}$, Modest$^{00\text{–}100}$, Moderate$^{00\text{–}100}$.

Days on feed impacted CSW ($P \le 0.05$; 0 d = 174.64, 28 d = 178.47, 56 d = 188.91 kg), tended to alter weight of fat yield ($P \le 0.09$; 0 d = 36.54, 28 d = 37.64, 56 d = 43.50 kg), and influenced weight of RMY ($P = 0.03$; 0 d = 111.59, 28 d = 112.57, 56 d = 120.58 kg; Table 2). Steers fed AB diet levels demonstrated increased CSW (+17.41 kg; $P < 0.01$), weight of fat yield (+10.22 kg; $P < 0.01$), and weight of RMY (+11.34 kg; $P < 0.01$) when compared to steers fed MA. Additionally, fat yield was increased ($P = 0.01$) by 2.89% as a percentage of CSW when fed at AB vs. MA. Zilpaterol hydrochloride treatment displayed an increase in weight of RMY (+10.29 kg; $P = 0.02$) and tended ($P = 0.06$) to increase RMY by 2.32% as a percentage of CSW as compared to C. In addition, CSW tended ($P = 0.08$) to increase by 8.34 kg when steers were supplemented ZH as compared to C. Days on feed, dietary intake level, or ZH treatment did not effect ($P \ge 0.38$) BY.

Round

Round subprimal values were altered by days on feed, dietary intake level and ZH treatment (Table 3). Days on feed impacted ($P \le 0.05$) weights of knuckle (0 d = 5.21, 28 d = 4.89, 56 d = 5.44 kg), top (inside) round (0 d = 8.43, 28 d = 8.92, 56 d = 9.38 kg), bottom (outside) round (0 d = 5.36, 28 d = 5.29, 56 d = 5.85 kg), and heel meat (0 d = 2.00, 28 d = 2.02, 56 d = 2.22 kg). Similarly, eye of round yield as a percentage of CSW was impacted ($P \le 0.03$) by days on feed (0 d = 1.51, 28 d = 1.37, 56 d = 1.36%). Steers fed at AB diet levels had heavier weights from the knuckle (+0.45 kg; $P = 0.01$), top (inside) round (+0.61 kg; $P = 0.01$), bottom (outside) round (+0.37 kg; $P = 0.03$), and heel meat (+0.12 kg;

Table 2. Effect of feeding beef steers for 0, 28, or 56 d on a maintenance (MA) or ad libitum (AB) dietary intake level and given a control (C) or Zilpaterol hydrochloride[1] (ZH) treatment on carcass cold side weight (CSW) and fabrication yields

	Treatment combination								*P* value					
Item	0	28 MA	28 AB	56 MAC	56 MAZH	56 ABC	56 ABZH	SEM	Overall	0 vs. 28	0 vs. 56	28 vs. 56	MA vs. AB	C vs. ZH
n	8	8	7	8	8	8	8							
CSW, kg	174.64^{c}	171.29^{c}	185.64^{bc}	175.36^{c}	183.51^{bc}	194.12^{ac}	202.64^{a}	5.49	<0.01	0.62	0.04	0.05	<0.01	0.08
Fat yield, kg	36.54^{bc}	33.87^{c}	41.40^{bc}	35.71^{c}	39.72^{bc}	53.76^{a}	44.80^{b}	3.75	0.01	0.80	0.09	0.07	<0.01	0.49
% CSW	20.93^{b}	19.87^{b}	21.96^{b}	20.40^{b}	21.06^{b}	26.51^{a}	21.51^{b}	1.36	0.04	1.00	0.34	0.22	0.01	0.12
Bone yield, kg	25.98	27.60	27.59	27.45	29.18	28.16	29.28	1.15	0.38					
% CSW	15.50	16.75	15.25	16.50	16.50	14.50	15.75	1.07	0.80					
Red meat yield, kg	111.59^{bc}	107.86^{c}	117.27^{bc}	111.20^{bc}	117.66^{b}	119.68^{b}	133.79^{a}	4.01	<0.01	0.85	0.06	0.03	<0.01	0.02
% CSW	64.01	63.66	62.86	63.59	62.92	59.10	64.42	1.23	0.07	0.60	0.26	0.46	0.20	0.06

[1] Merck Animal Health, Summit, NJ.

[a–c] Means within a row with different superscripts differ ($P < 0.05$).

$P = 0.03$) than those fed at MA. Additionally, the eye of round ($P = 0.09$) tended to be 0.13 kg heavier in steers fed at AB intake levels vs. those fed at MA. However, heel meat was increased ($P = 0.04$) by 0.16% as a percentage of CSW when fed at MA vs. those fed AB. Steers that were supplemented ZH demonstrated heavier weights of top (inside) round (+0.68 kg; $P = 0.01$), bottom (outside) round (+0.40 kg; $P = 0.04$), eye of round (+0.52 kg; $P < 0.01$), and heel meat (+0.21 kg; $P < 0.01$) than C steers. The knuckle ($P = 0.06$) tended to be 0.41 kg heavier for steers supplemented ZH than C steers. Compared to C steers, the eye of round tended ($P = 0.06$) to increase by 0.18% as a percentage of CSW when steers were supplemented ZH. No difference ($P \geq 0.26$) was detected in shank meat yield.

Loin/Flank

Subprimal weights from the loin were affected by days on feed, dietary intake level, and ZH treatment (Table 4). Days on feed altered ($P < 0.01$) the bottom sirloin tri-tip as a percentage of CSW (0 d = 0.79, 28 d = 0.69, 56 d = 0.69 %). The top sirloin butt ($P < 0.01$) was 0.74 kg heavier for steers fed at AB intake than those fed at MA. The bottom sirloin tri-tip increased ($P = 0.03$) as a percentage of CSW by 0.04% when steers were fed at MA intake as compared to AB steers. Supplementation of ZH resulted in a top sirloin butt that was 0.32 kg heavier ($P = 0.01$) than C steers. The peeled tenderloin from cattle supplemented ZH was 0.33 kg heavier ($P = 0.01$) than C cattle. No differences ($P \geq 0.12$) were detected for the strip loin, bottom sirloin flap, bottom sirloin ball tip, flank steak, or elephant ear across days on feed, dietary intake level or ZH treatment.

Rib/Plate

Rib and plate subprimals were affected by days on feed, dietary intake level, and ZH treatment (Table 5). Days on feed altered weights of back ribs ($P \leq 0.02$; 0 d = 1.81, 28 d = 1.99, 56 d = 2.16 kg), inside skirt ($P \leq 0.01$; 0 d = 1.18, 28 d = 0.81, 56 d = 0.68 kg), and outside skirt ($P \leq 0.01$; 0 d = 0.65, 28 d = 0.82, 56 d = 1.03 kg). When expressed as a percentage of CSW, days on feed impacted the inside skirt ($P \leq 0.01$; 0 d = 0.68, 28 d = 0.46, 56 d = 0.36%) and outside skirt ($P \leq 0.03$; 0 d = 0.37, 28 d = 0.46, 56 d = 0.55%). Steers that were fed at AB intake had greater weight of ribeye roll (+0.60 kg; $P < 0.01$), back ribs (+0.22 kg; $P < 0.01$), and blade meat (+0.22 kg; $P = 0.04$) than those fed at MA. Rib

Table 3. Effect of feeding beef steers for 0, 28, or 56 d on a maintenance (MA) or ad libitum (AB) dietary intake level and given a control (C) or Zilpaterol hydrochloride[1] (ZH) treatment on round primal yields

	Treatment combination								*P* value					
Item	0	28 MA	28 AB	56 MAC	56 MAZH	56 ABC	56 ABZH	SEM	Overall	0 v. 28	0 vs. 56	28 vs. 56	MA vs. AB	C vs. ZH
n	8	8	7	8	8	8	8							
NAMI 167A—knuckle (peeled), kg	5.21^{b}	4.64^{c}	5.13^{bc}	5.17^{b}	5.28^{b}	5.30^{b}	6.01^{a}	0.21	<0.01	0.21	0.34	<0.01	0.01	0.06
% CSW	2.99	2.70	2.83	2.96	2.88	2.74	2.97	0.11	0.36					
NAMI 168—top (inside) round, kg	8.43^{c}	8.66^{bc}	9.18^{b}	8.94^{bc}	9.17^{b}	9.14^{b}	10.26^{a}	0.27	<0.01	0.15	<0.01	0.05	0.01	0.01
% CSW	4.83	5.07	4.91	5.10	5.00	4.72	5.07	0.13	0.34					
NAMI 171B—bottom (outside) round, kg	5.36^{bc}	5.03^{c}	5.55^{bc}	5.64^{b}	5.76^{b}	5.66^{b}	6.33^{a}	0.22	0.01	0.81	0.05	0.01	0.03	0.04
% CSW	3.07	2.94	2.98	3.22	3.14	2.92	3.13	0.08	0.15					
NAMI 171C—eye of round, kg	2.64^{ab}	2.40^{c}	2.50^{bc}	2.42^{bc}	2.56^{bc}	2.42^{bc}	2.86^{a}	0.10	0.02	0.14	0.50	0.19	0.09	<0.01
% CSW	1.51^{a}	1.40^{ab}	1.34^{bc}	1.38^{b}	1.40^{b}	1.25^{c}	1.41^{ab}	0.05	0.02	0.03	0.01	0.71	0.14	0.06
NAMI 171F—heel Meat, kg	2.00^{cd}	1.91^{d}	2.12^{bc}	2.13^{bc}	2.23^{b}	2.10^{bc}	2.40^{a}	0.06	<0.01	0.79	<0.01	<0.01	0.03	<0.01
% CSW	1.15^{abc}	1.12^{bc}	1.11^{bc}	1.21^{a}	1.22^{a}	1.09^{c}	1.19^{ab}	0.03	0.03	0.45	0.39	0.04	0.04	0.12
Shank meat, kg	2.01	2.01	2.12	2.11	2.12	2.09	2.22	0.07	0.45					
% CSW	1.15	1.18	1.12	1.20	1.16	1.08	1.10	0.04	0.26					

[1] Merck Animal Health, Summit, NJ.

$^{a–d}$Means within a row with different superscripts differ ($P < 0.05$).

Table 4. Effect of feeding beef steers for 0, 28, or 56 d on a maintenance (MA) or ad libitum (AB) dietary intake level and given a control (C) or Zilpaterol hydrochloride[1] (ZH) treatment on loin and flank primal yields

	Treatment combination								*P* value					
Item	0	28 MA	28 AB	56 MAC	56 MAZH	56 ABC	56 ABZH	SEM	Overall	0 vs. 28	0 vs. 56	28 vs. 56	MA vs. AB	C vs. ZH
n	8	8	7	8	8	8	8							
NAMI 180—strip loin, kg	4.56	4.26	4.73	4.42	4.59	4.80	5.09	0.21	0.13					
% CSW	2.61	2.49	2.56	2.52	2.50	2.48	2.53	0.11	0.98					
NAMI 184C—top sirloin butt, kg	5.69^{c}	5.60^{c}	6.32^{ab}	5.69^{c}	5.90^{bc}	6.32^{bc}	6.76^{a}	0.22	0.01	0.26	0.12	0.67	<0.01	0.01
% CSW	3.26	3.35	3.36	3.25	3.23	3.10	3.33	0.13	0.67					
NAMI 185A—bottom sirloin flap, kg	2.02	1.58	1.77	1.79	1.87	1.84	2.09	0.17	0.18					
% CSW	1.16	0.92	0.95	1.02	1.01	0.95	1.03	0.07	0.27					
NAMI 185B—bottom sirloin ball tip, kg	0.52	0.67	1.75	0.51	0.54	0.49	0.70	0.17	0.84					
% CSW	0.30	0.39	0.27	0.28	0.29	0.25	0.34	0.07	0.83					
NAMI 185D—bottom sirloin tri-tip, kg	1.37	1.20	1.29	1.28	1.30	1.26	1.36	0.07	0.60					
% CSW	0.79^{a}	0.70^{bcd}	0.68^{bcd}	0.73^{ab}	0.71^{bc}	0.65^{d}	0.67^{cd}	0.03	0.01	<0.01	<0.01	0.88	0.03	0.98
NAMI 189D—peeled tenderloin, kg	2.14	2.15	2.15	2.20	2.27	2.01	2.59	0.15	0.10	0.94	0.44	0.37	0.69	0.01
% CSW	1.22	1.25	1.14	1.25	1.24	1.04	1.28	0.07	0.16					
NAMI 193—flank steak, kg	0.92	0.79	0.89	0.83	0.83	0.89	0.96	0.05	0.12					
% CSW	0.53	0.46	0.42	0.47	0.45	0.46	0.47	0.03	0.17					
Elephant ear, kg	1.70	1.24	1.28	1.48	1.35	1.60	1.56	0.20	0.47					
% CSW	0.98	0.72	0.68	0.84	0.73	0.82	0.77	0.10	0.36					

[1] Merck Animal Health, Summit, NJ.

[a–d] Means within a row with different superscripts differ ($P < 0.05$).

Table 5. Effect of feeding beef steers for 0, 28, or 56 d on a maintenance (MA) or ad libitum (AB) dietary intake level and given a control (C) or Zilpaterol hydrochloride[1] (ZH) treatment on rib and plate primal yields

	Treatment combination								*P* value					
Item	0	28 MA	28 AB	56 MAC	56 MAZH	56 ABC	56 ABZH	SEM	Overall	0 vs. 28	0 vs. 56	28 vs. 56	MA vs. AB	C vs. ZH
n	8	8	7	8	8	8	8							
NAMI 112A—ribeye roll, lip on, kg	5.67	5.56	5.93	5.56	5.41	6.04	6.34	0.27	0.07	0.79	0.52	0.66	<0.01	0.70
% CSW	3.25	3.24	3.20	3.17	2.94	3.11	3.13	0.10						
NAMI 124—rib back ribs, kg	1.81^{c}	1.86^{bc}	2.11^{ab}	2.08^{ab}	2.04^{b}	2.28^{a}	2.25^{a}	0.10	<0.01	0.09	<0.01	0.02	<0.01	0.70
% CSW	1.03	1.09	1.14	1.19	1.11	1.18	1.11	0.05	0.15					
NAMI 109B—rib blade meat, kg	1.98^{b}	1.93^{b}	2.27^{b}	2.16^{b}	2.18^{b}	1.98^{b}	2.69^{a}	0.15	<0.01	0.51	0.10	0.21	0.04	0.01
% CSW	1.14	1.13	1.22	1.23	1.19	1.02	1.33	0.08	0.09	0.69	0.49	0.76	0.90	0.05
NAMI 121D—inside skirt, kg	1.18^{a}	0.81^{b}	0.80^{b}	0.62^{b}	0.68^{b}	0.77^{b}	0.63^{b}	0.11	0.01	0.01	<0.01	0.13	0.69	0.63
% CSW	0.68^{a}	0.48^{b}	0.43^{bc}	0.36^{bc}	0.37^{bc}	0.40^{bc}	0.31^{bc}	0.06	<0.01	0.01	<0.01	0.06	0.63	0.46
NAMI 121C—outside skirt, kg	0.65^{e}	0.75^{de}	0.88^{bcde}	1.04^{abc}	0.88^{cd}	1.11^{a}	1.09^{ab}	0.09	<0.01	0.14	<0.01	0.01	0.03	0.22
% CSW	0.37^{d}	0.44^{cd}	0.47^{bcd}	0.59^{a}	0.48^{c}	0.57^{ab}	0.54^{abc}	0.05	0.01	0.18	<0.01	0.03	0.45	0.06

[1] Merck Animal Health, Summit, NJ.

$^{a–e}$Means within a row with different superscripts differ ($P < 0.05$).

blade meat increased in weight (+0.37 kg; $P = 0.01$) as well as a percentage of CSW (0.13%; $P = 0.05$) when steers were supplemented ZH. The outside skirt from the plate was 0.14 kg heavier ($P = 0.03$) for steers fed AB intake than those fed MA and tended ($P = 0.06$) to decrease as a percentage of CSW by 0.07% when steers were supplemented ZH.

Chuck/Brisket

Subprimal weights from the chuck and brisket were affected by days on feed, dietary intake level, and ZH treatment (Table 6). Days on feed impacted weights from the shoulder tender ($P \leq 0.04$; 0 d = 0.34, 28 d = 0.39, 56 d = 0.43 kg), chuck eye roll ($P \leq 0.01$; 0 d = 7.23, 28 d = 7.36, 56 d = 8.59 kg), and brisket ($P = 0.03$; 0 d = 7.12, 28 d = 6.37, 56 d = 6.68 kg). When expressed as a percentage of the CSW, days on feed altered the chuck eye roll ($P \leq 0.03$; 0 d = 4.14, 28 d = 4.11, 56 d = 4.55%) and brisket ($P \leq 0.01$; 0 d = 4.08, 28 d = 3.56, 56 d = 3.48%). Steers fed AB intake had greater weight of shoulder tender (+0.04 kg; $P = 0.04$), chuck eye roll (+0.74 kg; $P = 0.01$), and top blade (+0.15 kg; $P = 0.05$) than steers fed MA. The shoulder clod ($P = 0.06$) tended to increase as a percentage of CSW by 0.16% when fed at MA vs. AB intake. Zilpaterol hydrochloride treatment increased the weights of the shoulder tender (+0.05 kg; $P = 0.03$) and top blade (+0.27 kg; $P < 0.01$) as compared to C steers with a tendency ($P \leq 0.10$) to alter the weights of the shoulder clod and mock tender. As a percentage of CSW, the shoulder clod tended ($P = 0.06$) to increase when ZH was supplemented as compared to C steers. Short rib and pectoral meat from the chuck were not affected by treatment ($P \geq 0.24$). The brisket ($P < 0.01$) was increased by 0.87 kg over MA steers when steers were fed AB intake and was increased by 0.99 kg over C steers when ZH was supplemented. When expressed as a percentage of CSW, the brisket ($P = 0.01$) was increased by 0.27% over C steers when ZH was supplemented.

DISCUSSION

The supplementation of ZH has demonstrated beneficial effects on carcass weight and increased subprimal weights when fed during the last 20 d of the feeding period. Plascencia et al. (1999) first reported an increase in carcass weight as well as an increase of (bone- and trim-in) primal cuts, boneless closely trimmed primal cuts, and boneless closely trimmed retail cuts from cattle supplemented ZH.

A study conducted by Avendaño-Reyes et al. (2006) reported an increase in carcass weights by 7% which resulted in an increase of carcass yield from steers supplemented ZH. Boler et al. (2009) and Hilton et al. (2010) reported similar results; an increase of chilled CSW as well as saleable yield when ZH was included in the diet. Chilled side weight was increased by 6.22 kg which resulted in an increased saleable yield of 6.40 kg. In the present study, cold CSW, similar to chilled side weight, was increased by 8.34 kg and RMY (RMY%) was increased by 10.29 kg as well as by 2.32% as a percentage of CSW from steers supplemented ZH.

There were no differences detected in fat yield and BY when expressed as a weight or as a percentage of cold carcass side weight when ZH was included in the diet. In agreement, Avendaño-Reyes et al. (2006), Boler et al. (2009), and Leheska et al. (2009) reported no effect on fat yield when steers were supplemented ZH. However, Hilton et al. (2010) detected no difference in the quantity of fat trim but did detect a decrease in fat yield by 0.58% units as a percentage of CSW with ZH supplementation. Unlike the current study and the studies that reported no differences in fat yield, the study by Hilton et al. (2010) demonstrated a larger sample size ($n = 801$) which may explain why differences existed in these traits between studies.

The supplementation of ZH in the diet has demonstrated an increase in weight of various subprimals when expressed as a weight as well as a percentage of carcass weight. Plascencia et al. (1999) reported increased weights from retail cuts that include the knuckle, inside skirt, neck, inside round, and triangle. Similarly, Hilton et al. (2009) reported increased subprimal yields of the shoulder clod, chuck tender, knuckle, top round, outside round, eye of round, strip loin, top sirloin butt, bottom sirloin butt ball tip, full tenderloin, and flank steak with the supplementation of ZH. In the present study, similar results occurred in which subprimal weights were increased due to the inclusion of ZH in the diet. The subprimals affected by ZH include the knuckle, top (inside) round, bottom (outside) round, eye of round, heel meat, top sirloin butt, peeled tenderloin, rib blade meat, chuck shoulder clod, chuck shoulder tender, chuck (mock) tender, chuck flat iron, and the brisket. Subprimal weights from the round demonstrated the greatest effects from ZH supplementation, which coincide with results from previous studies. Boler et al. (2009) and Hilton et al. (2010) both reported increased weights from the knuckle, inside round, eye of round, and heel. When expressed as a percentage

Table 6. Effect of feeding beef steers for 0, 28, or 56 d on a maintenance (MA) or ad libitum (AB) dietary intake level and given a control (C) or Zilpaterol hydrochloride[1] (ZH) treatment on chuck and brisket primal yields

	Treatment combination								*P* value					
Item	0	28 MA	28 AB	56 MAC	56 MAZH	56 ABC	56 ABZH	SEM	Overall	0 vs. 28	0 vs. 56	28 vs. 56	MA vs. AB	C vs. ZH
n	8	8	7	8	8	8	8							
NAMI 114—chuck shoulder clod, kg	3.87	3.48	3.53	3.38	4.02	3.56	3.98	0.21	0.06	0.12	0.50	0.15	0.66	<0.01
% CSW	2.22	2.04	1.90	1.94	2.20	1.83	1.97	0.13	0.09	0.08	0.06	0.87	0.06	0.05
NAMI 114F—chuck shoulder tender, kg	0.34^{d}	0.37^{cd}	0.41^{bc}	0.40^{bcd}	0.43^{ab}	0.42^{bc}	0.48^{a}	0.02	<0.01	0.08	<0.01	0.04	0.04	0.03
% CSW	0.20	0.22	0.22	0.23	0.23	0.21	0.24	0.01	0.21					
NAMI 116D—chuck eye roll, kg	7.23^{d}	7.05^{d}	7.66^{cd}	8.06^{bcd}	8.32^{abc}	9.03^{a}	8.96^{ab}	0.57	<0.01	0.79	<0.01	<0.01	0.01	0.77
% CSW	4.14^{b}	4.11^{b}	4.11^{b}	4.58^{a}	4.54^{a}	4.66^{a}	4.42^{ab}	0.25	0.05	0.88	0.03	<0.01	0.90	0.34
NAMI 116B—chuck (mock) tender, kg	1.33	1.32	1.39	1.34	1.44	1.40	1.55	0.07	0.10	0.82	0.19	0.17	0.11	0.03
% CSW	0.77	0.77	0.75	0.77	0.79	0.72	0.77	0.04	0.79					
NAMI 130A—chuck short rib, kg	1.43	1.33	1.50	1.43	1.43	1.55	1.64	0.09	0.24					
% CSW	0.82	0.77	0.80	0.82	0.78	0.81	0.81	0.05	0.98					
NAMI 114D—chuck top blade, kg	2.15^{b}	2.07^{b}	2.23^{b}	2.09^{b}	2.29^{ab}	2.16^{b}	2.51^{a}	0.10	0.03	1.00	0.31	0.20	0.05	<0.01
% CSW	1.23	1.22	1.21	1.19	1.25	1.12	1.24	0.07	0.68					
NAMI 115D—pectoral meat, kg	0.80	0.72	0.83	0.69	0.75	0.69	0.64	0.09	0.68					
% CSW	0.46	0.43	0.45	0.39	0.41	0.36	0.32	0.05	0.23					
NAMI 120—brisket, whole boneless, kg	7.12^{ab}	6.09^{cd}	6.64^{abc}	5.71^{d}	6.62^{bc}	6.66^{abc}	7.73^{a}	0.28	<0.01	0.03	0.08	0.36	<0.01	<0.01
% CSW	4.08^{a}	3.56^{b}	3.56^{b}	3.25^{c}	3.60^{b}	3.43^{bc}	3.62^{b}	0.11	<0.01	<0.01	<0.01	0.38	0.44	0.01

[1] Merck Animal Health, Summit, NJ.

$^{a–d}$Means within a row with different superscripts differ ($P < 0.05$).

of cold carcass weight, ZH increased the eye of round, peeled tenderloin, rib blade meat, outside skirt, chuck shoulder clod, and the brisket.

In the present study, the results support the use of the β adrenergic agonist ZH functioning as an efficacious repartitioning agent in beef cattle. This function of ZH has been reported (Leheska et al., 2009) as an increase in protein and muscle deposition indicative of an improvement in carcass composition. However, Hilton et al. (2009) describes the repartitioning capacity of ZH as an increase in carcass protein and moisture and a decrease in carcass fat. Although the present study detected no decrease in fat yield, it is evident that ZH is responsible for protein and muscle deposition due to the increase in weight of several economically important subprimal cuts.

Furthermore, the effects of extended days on feed on carcass cutability and fabrication yields have been studied. Wheeler et al. (1989) reported changes in carcass composition when cattle were fed for longer periods of time. With an extended feeding period, carcasses produced increased percentages of trimmable fat with decreased percentages of saleable product (Wheeler et al., 1989). Similarly, Rathmann et al. (2009) reported increased trimmable fat with increasing days on feed in addition to a strong influence on subprimal yields. As days on feed increased, subprimal lean yield was continually diminished (Rathmann et al., 2009). In comparison, extended days on feed in serially harvested Holsteins resulted in a linear decrease in percentage BY and RMY in conjunction with a linear increase in percentage TFY (May et al., 2017). In the present study, extended days on feed demonstrated similar responses to previous research as fat yield increased as a percentage by 1.44% from day 0 to 56 while RMY decreased by 1.50% from day 0 to 56. Moreover, percentage BY remained constant throughout the present study.

As shown in previous research, improvements in feed efficiency and increased carcass protein and water content were observed when cattle were fed restricted intake levels (80% and 90% of AB) rather than allowed AB access to feed (Murphy and Loerch, 1994). Further improvements may also be found in carcass protein and water when cattle are fed a MA diet level in combination with ZH at the end of the feeding period. Reductions in fat yield were demonstrated with steers given a MA diet level when compared to steers allowed AB access to feed. This reduction in carcass fat was accompanied by an increase in RMY. Similar responses in reduced carcass fat content were observed in lambs (Glimp et al., 1989) and feedlot steers and heifers (Hicks et al., 1990) by restricting feed intake. In comparison, Murphy and Loerch (1994) reported reductions in carcass fat content in conjunction with an increase in carcass water and protein.

In conclusion, days on feed, dietary intake level, and ZH treatment all demonstrated effects on subprimal yields. Subprimal weights were significantly increased from steers fed an AB dietary intake level as well as steers supplemented ZH. Zilpaterol hydrochloride demonstrated the greatest effect on the round primal by increasing the weight of each subprimal cut while tending to increase the percentage of RMY and decreasing the percentage of fat yield. The percentage of TFY was also impacted by days on feed as well as dietary intake level. These results indicate that intake level during the last 56 d of the finishing period and ZH supplementation affect subprimal yields. This information provides producers with the opportunity to efficiently produce more saleable product and increase carcass value.

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