Effects of zilpaterol hydrochloride and zilpaterol hydrochloride withdrawal time on beef carcass cutability and tenderness

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STORY IN BRIEF

The impact of zilpaterol hydrochloride (ZH) on carcass yield, composition, and tenderness was evaluated using 384 beef steers in a randomized complete block design. Main effects were the addition of 0 or 8.3 mg/kg ZH for the final 20 d of feeding and each inclusion level was paired with withdrawal periods of 3, 10, 17, or 24 d. The two animals with weights closest to the pen average were selected for carcass fabrication to determine carcass yield, composition, and tenderness. The carcasses from animals fed ZH had greater individual side weights. Carcass fat determinations were unchanged by ZH. Weights of the strip loin, peeled tenderloin, and top sirloin butt were all improved with ZH. When expressed as a proportion of carcass weight, ZH increased percentage of carcass in the top sirloin butt, bottom sirloin tri-tip, top inside round, bottom round flat, and flank steak. Shear force values were higher at each of the 3 aging times, 7 d, 14 d, and 21 d, in steaks from ZH fed steers compared to control steers. Carcass weights and yields were improved with ZH feeding. Tenderness was slightly reduced with ZH supplementation. Zilpaterol hydrochloride can be a valuable supplement to finishing beef steers to improve carcass lean yields and composition.

Key Words: beef, beta-agonist, cutability, tenderness

INTRODUCTION

The use of β-adrenergic agonists (β-AA) to improve feed efficiency and enhance carcass composition in livestock species has been well documented since the early 1980's. Many β-AA act as repartitioning agents and have been shown to enhance lean meat production in many animal species. Zilpaterol hydrochloride (Zilmax®, Intervet, Millsboro DE, USA) is a β-AA that has been approved in Mexico and South Africa for over 10 yr; however, it was not until 2006 that the compound was approved by the FDA for use in feedlot cattle in the U.S.

Zilpaterol hydrochloride (ZH) is marketed as a compound that will increase rate of gain, improve feed efficiency, and increase carcass leanness in cattle fed in confinement systems. Initial studies by Avendano-Reyes et al. (2006) documented an increase in final body weight, increased ADG, and an improvement in G:F for cattle supplemented with ZH. Additionally, Avendano-Reyes et al. (2006) documented an increase in hot carcass weight (HCW), carcass yield, and loin muscle area with ZH. While the study by Avendano-Reyes et al. (2006) indicated a tendency for ZH fed cattle to have decreased 12th rib fat, a study by Plascencia et al. (1999) found no effect on 12th rib fat thickness with ZH inclusion. When combined with an increase in loin muscle area and HCW, calculated yield grade was decreased (i.e., improved), which was an indication of ZH ability to improve lean yield. Zilpaterol hydrochloride has also been shown to increase weight of gross primal and boneless closely trimmed primals, and boneless closely trimmed retail cuts as a percentage of carcass weight, when carcass weights were held constant (Plascencia et al., 1999).

Additionally, harvesting a lot of cattle on the same date can be problematic and may require longer than expected withdrawal periods and may result in withdrawal periods in excess of 3 d. If compounds such as ZH are used during the last 20 d of finishing and an appropriate 3 d WT has been scheduled, the extended time on feed can result in extended WT. Furthermore, ZH has been shown to significantly increase Warner-Bratzler shear (WBS) values of loin muscle steaks; however, these reported values still range from severe to mild increases in WBS values (Avendano-Reyes et al., 2006; Hilton el al., 2009).

The objective of this study was to determine the effects of zilpaterol hydrochloride and WT on beef carcass lean to fat ratios as well as carcass tenderness. The studies were conducted on carcasses from Holland et al. (2009).

MATERIALS AND METHODS

A subset (n = 128) selected from 384 (BW = 356 ± 23.3 kg) British and British × Continental steers was used in this experiment. Steers were separated into two weight blocks and randomly assigned to pens (32 pens per block; 4 pens per treatment combination; 6 steers/pen). Within each block, pens were randomly assigned to a 2 × 4 factorial arrangement of treatments. Main effects were the addition of 0 or 8.3 mg/kg (100% DM basis) ZH fed for 20 d at the end of the feeding period and each supplementation level was paired with withdrawal periods of 3, 10, 17, or 24 d prior to slaughter (Holland et al., 2009). Zilpaterol treatment began at d 95 and d 123 for heavy and light blocks, respectively.

Harvest and Carcass Selection. The two steers whose final BW was closest to their respective pen average were selected for intensive fabrication after harvest (n = 128). All animals were harvested, after meeting their predetermined withdrawal time, following USDA guidelines for humane slaughter. After harvest and chilling, carcasses were ribbed at the 12th rib, and USDA Quality and Yield Grades and carcass traits were recorded (USDA, 1997). All carcass data was collected by trained Oklahoma State University personnel.

Carcass Fabrication. All carcasses were held at the Robert M. Kerr Food and Agriculture Products Center (FAPC) in holding coolers (0° to 4°C) until fabrication. Cold side weights (CSW) were recorded prior to fabrication using a certified on-line rail scale. Carcasses were then fabricated into various NAMP subprimals similar to a typical industry cutout. All trim from fabrication was segregated into one of three lean trim categories: 90% lean/10% fat (90/10), 80% lean/20% fat (80/20), or 50% lean/50% fat (50/50). Kidney knob fat, all trimmed fat, and all bones were also collected and weighed. After all weights of each side were recorded and entered, fabrication yield was calculated to ensure that 99% to 100.5% of CSW was recovered. Weights were recorded for all previously mentioned products of fabrication and were expressed as a percentage of CSW.

Postmortem Aging and Strip Loin Fabrication. Upon completion of fabrication, strip loins (IMPS 180) were fabricated for shear force analysis. From the anterior end of the strip loin, three 2.54 cm steaks were cut and assigned to one of three aging times (7 d, 14 d, or 21 d) based on the order the steaks were cut from the strip loin. After cutting, all steaks were individually vacuum packaged and aged for their respective time under refrigeration at 0° to 4°C. After the assigned aging period, samples were frozen in a blast freezer (-20° to -40°C); and frozen, samples were held in a freezer (-10°C) until further analysis.

Warner-Bratzler Shear Force. Warner-Bratzler shear force was completed using the American Meat Science Association guidelines (AMSA, 1995), with the following modification: Steaks were cooked using "The Next Generation" George Foreman Digital Grill (Model GRP99) to a medium degree of doneness (~71°C). Steaks were then placed on trays, covered with poly-vinyl wrap and refrigerated overnight. Following the overnight chill, two cores from each of the lateral, middle, and medial portions, for a total of six cores (1.27 cm), from each steak were removed parallel to the longitudinal orientation of the muscle fibers. Cores were shorn using a Warner-Bratzler Shear Testing Machine (G-R Elec. Mfg. Co., Manhattan, KS), and the peak shear force was recorded in kg and the average was determined.

Data Analysis. In this study the interaction of ZH and WT was not significant so only main effect means are reported. Data were analyzed using the mixed model procedures of SAS. Analysis of variance for a complete random design with the main effects of ZH and WT was analyzed. Two weight blocks (heavy weight and light weight) were included in the model as fixed variables; block was not significant so results are pooled over block effect. Carcass side was the experimental unit used for analysis. For ZH and WT, all carcasses (control and ZH fed) were included together for analysis. Least squares means were generated and separated using a pairwise t-test when the model displayed a treatment effect ($\alpha < 0.05$). Miller et al. (2001) used a range from 3.92 to 4.50 kg as intermediate and tough as greater than 5.42 kg when comparing beef steaks. The frequency of tender, intermediate, and tough steaks was determined using the method established by Miller et al. (2001) and were analyzed using the Chi-square procedure.

RESULTS AND DISCUSSION

Zilpaterol Hydrochloride Withdrawal Time. There was no interaction of ZH and withdrawal time for any measure traits, indicating that withdrawal length had no impact on ZH effects.

Zilpaterol Hydrochloride. Results for growth performance characteristics, as well as USDA grade data, were reported by Holland et al. (2009). Zilpaterol hydrochloride inclusion in the diet had a significant effect on individual side weights with ZH supplemented animals having heavier ($P = 0.008$) weights as compared to control fed cattle (184.30 kg vs. 180.87 kg, respectively). Furthermore, there was an increase (< 0.001) in the percentage of 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) with ZH supplementation as compared to controls (51.49% vs. 50.03%, respectively. However, no effect of ZH treatment on lean trim percentages or percent carcass fat was observed. A significant reduction ($P = 0.05$) in total bone weight between ZH and control steers was documented (35.27 kg vs. 35.96 kg respectively), which resulted in a decreased ($P < 0.001$) percentage of bone in the carcass side between ZH and control fed steers (19.15% vs. 19.90%, respectively). Due to a decrease in percent bone and with percent fat being unchanged, the increase in carcass weight is presumed to be due to an increase in carcass lean.

While most major primals from the forequarter, such as the shoulder clod, chuck roll, and ribeye roll were not affected by ZH treatment, several cuts increased in weight with ZH inclusion. A significant increase in the weight of pectoral meat (*P* = 0.03), rib blade meat (*P* = 0.03), and pastrami meat (*P* = 0.04) was shown with ZH feeding. Zilpaterol hydrochloride inclusion also resulted in increased weights of the whole brisket (*P* < 0.001) (Table 1).

Table 1. Effects of ZH inclusion into the diet and withdrawal time of ZH prior to slaughter on various wholesale beef cuts from the forequarter (n = 127).

	ZH			Withdrawal (d)					
Item	0 mg/kg	8.3 mg/kg	Pr > F	3	10	17	24	Pr < F	SEM
Shoulder clod, trimmed, kg	8.88	9.02	0.20	8.41^{c}	9.05^{b}	9.53^{a}	8.81^{b}	< 0.001	0.11
Shoulder Clod trimmed[1]	4.91	4.90	0.88	4.72^{c}	4.90^{b}	5.18^{a}	4.80^{bc}	< 0.001	0.06
Chuck Shoulder Tender, kg	0.51	0.51	0.88	0.48^{b}	0.63^{a}	0.48^{b}	0.46^{b}	< 0.001	0.02
Chuck Shoulder Tender[1]	0.28	0.28	0.66	0.26^{b}	0.34^{a}	0.26^{b}	0.25^{b}	< 0.001	0.01
Chuck Roll, kg	13.74	14.12	0.22	13.45^{b}	13.48^{b}	14.18^{ab}	14.61^{a}	0.02	0.43
Chuck Roll[1]	7.59	7.66	0.69	7.56^{ab}	7.29^{b}	7.69^{ab}	7.96^{a}	0.02	0.23
Chuck Mock Tender, kg	1.53	1.75	0.23	1.47	1.61	1.90	1.58	0.39	0.18
Chuck Mock Tender[1]	0.85	0.95	0.30	0.83	0.87	1.04	0.86	0.46	0.10
Chuck Short Ribs, kg	1.37	1.36	0.87	1.04	1.39	1.41	1.38	0.49	0.06
Chuck Short Ribs[1]	0.76	0.74	0.84	0.72	0.76	0.76	0.75	0.81	0.03
Pectoral Meat, trimmed, kg	0.89	0.99	0.03	0.88	0.99	0.95	0.94	0.37	0.08
Pectoral Meat, trimmed [1]	0.49	0.54	0.06	0.49	0.54	0.52	0.51	0.60	0.04
Rib Blade Meat, kg	1.56	1.71	0.03	1.78^{a}	1.81^{a}	1.42^{b}	1.54^{b}	< 0.001	0.09
Rib Blade Meat[1]	0.86	0.93	0.07	1.00^{a}	0.98^{a}	0.77^{b}	0.84^{b}	< 0.001	0.05
Ribeye Roll, kg	5.62	5.72	0.20	5.63	5.72	5.71	5.63	0.80	0.10
Ribeye Roll[1]	3.10	3.11	0.88	3.16	3.10	3.10	3.07	0.44	0.05
Rib Back Ribs, kg	1.43	1.44	0.89	1.39^{b}	1.59^{a}	1.41^{b}	1.35^{b}	< 0.001	0.34
Rib Back Ribs[1]	0.79	0.78	0.55	0.78^{b}	0.86^{a}	0.77^{b}	0.74^{b}	< 0.001	0.02
Pastrami Meat, kg	0.59	0.65	0.04	0.56^{b}	0.66^{a}	0.59^{b}	0.67^{a}	< 0.01	0.34
Pastrami Meat[1]	0.33	0.35	0.10	0.31^{c}	0.36^{ab}	0.32^{bc}	0.37^{a}	0.01	0.02
Brisket Whole, packer trim, kg	5.62	6.05	< 0.001	5.30^{b}	5.48^{b}	6.76^{a}	6.31^{a}	< 0.001	0.14
Brisket Whole, packer trim[1]	3.11	3.28	< 0.01	2.97^{b}	2.97^{b}	3.40^{a}	3.44^{a}	< 0.001	0.07

[a, b, c] Within a trait and main effect means with different superscripts differ (P < 0.05).

[1]Listed as a percentage of cold side weight.

More of the muscles and primals from the hindquarter exhibited greater response to ZH as compared to those from the forequarter. Higher valued cuts, such as the strip loin (*P* = 0.01), peeled tenderloin (*P* = 0.02), and top sirloin butt (*P* < 0.001) all increased in weight with ZH supplementation. In addition to these cuts, several other cuts from the hindquarter were heavier with ZH, including the bottom sirloin tri-tip (*P* = 0.005), top inside round (*P* < 0.001), bottom round flat (*P* < 0.001), eye of round (*P* = 0.02), and flank steak (*P* = 0.005). Also, an increase in weight was observed in the heel (*P* = 0.02) and the shank (*P* < 0.01) with the inclusion of ZH. While several of the primal and cut weights significantly increased, only the top sirloin butt (*P* = 0.006), bottom sirloin tri-tip (*P* = 0.02), top inside round (*P* = 0.002), bottom round flat (*P* = 0.001), and the flank steak (*P* = 0.02) increased when cut weight was expressed as a percentage of CSW (Table 2).

Table 2. Effects of ZH inclusion into the diet and withdrawal time of ZH prior to slaughter on various wholesale beef cuts from the hindquarter (n = 127).

	ZH			Withdrawal (d)					
Item	0 mg/kg	8.3 mg/kg	Pr > F	3	10	17	24	Pr < F	SEM
Strip Loin, kg	4.87	5.09	0.01	4.93	5.12	4.94	4.94	0.41	0.09
Strip Loin[1]	2.69	2.76	0.09	2.76	2.76	2.68	2.69	0.36	0.04
Peeled Tender, kg	2.66	2.76	0.02	2.52^{c}	2.86^{a}	2.72^{b}	2.74^{ab}	< 0.001	0.09
Peeled Tender[1]	1.47	1.50	0.22	1.42^{c}	1.55^{a}	1.48^{bc}	1.49^{ab}	< 0.01	0.05
Top Sirloin Butt, kg	5.47	5.82	< 0.001	5.69^{b}	6.06^{a}	5.49^{bc}	5.34^{c}	< 0.001	0.15
Top Sirloin Butt[1]	3.03	3.16	< 0.01	3.20^{a}	3.28^{a}	2.98^{b}	2.91^{b}	< 0.001	0.07
Bottom Sirloin Ball-Tip, kg	0.58	0.66	0.07	0.61^{ab}	0.69^{a}	0.68^{a}	0.50^{b}	0.01	0.05
Sirloin Ball Tip[1]	0.32	0.36	0.12	0.34^{ab}	0.37^{a}	0.37^{a}	0.27^{b}	0.02	0.02
Bottom Sirloin Tri-Tip, kg	0.99	1.08	< 0.01	1.02^{b}	1.14^{a}	1.08^{ab}	0.90^{c}	< 0.001	0.04
Sirloin Tri-Tip[1]	0.55	0.59	0.02	0.57^{a}	0.62^{a}	0.59^{a}	0.49^{b}	< 0.001	0.02
Knuckle, peeled, kg	5.16	5.26	0.34	4.93^{b}	5.27^{a}	5.29^{a}	5.34^{a}	0.02	0.12
Knuckle, peeled[1]	2.85	2.85	0.99	2.77	2.85	2.88	2.91	0.20	0.06
Top Inside Round, kg	9.71	10.36	< 0.001	9.72	10.21	10.23	10.01	0.06	0.15
Top Inside Round[1]	5.37	5.62	< 0.01	5.46	5.53	5.56	5.43	0.62	0.08
Bottom Round Flat, kg	6.59	7.14	< 0.001	6.75	6.76	6.90	7.04	0.42	0.14
Bottom Round Flat[1]	3.64	3.87	< 0.01	3.79	3.66	3.75	3.83	0.39	0.07
Eye of Round, kg	2.59	2.78	0.02	2.52^{b}	2.80^{a}	2.78^{a}	2.63^{ab}	0.03	0.08
Eye of Round[1]	1.43	1.50	0.08	1.41	1.52	1.51	1.43	0.16	0.04
Heel Meat, kg	2.27	2.39	0.02	2.29	2.36	2.39	2.29	0.31	0.05
Heel Meat[1]	1.26	1.30	0.10	1.28	1.28	1.30	1.25	0.54	0.02
Shank Meat, kg	2.58	2.71	< 0.01	2.59^{b}	2.61^{b}	2.62^{b}	2.75^{a}	0.05	0.07
Shank Meat[1]	1.43	1.47	0.08	1.46^{ab}	1.41^{b}	1.42^{b}	1.50^{a}	0.05	0.04
Flank Steak, kg	0.82	0.89	< 0.01	0.79^{c}	0.90^{a}	0.84^{bc}	0.89^{ab}	< 0.01	0.03
Flank Steak[1]	0.45	0.48	0.02	0.44^{c}	0.49^{a}	0.46^{bc}	0.48^{ab}	0.02	0.02

[a, b, c] Within a row and main effect means with different superscripts differ (*P* < 0.05).

[1] Listed as a percentage of cold side weight.

As shown in this study, the response to ZH seemed to be greater in hindquarter muscles as compared to those recovered from the forequarter. Previous studies indicate that type II fibers have a greater response to β-AA- stimulations as compared to other muscle fiber types (Smith et al., 1995). Furthermore, as reported by Kirchofer et al. (2002) there is a greater variation among fiber types within muscles of the chuck while the round is comprised mainly of white muscle fibers. These findings could explain the variation in response between muscles within this study, as those muscles with a greater proportion of white fibers had a greater response.

While it is understood that feeding β-AA to livestock increases lean: fat ratios, various theories remain as to how these compounds truly affect muscle and fat synthesis. While researchers still debate the true mechanisms of increased muscle accretion as being an increase in muscle cell hypertrophy, a reduction in muscle protein degradation, or a combination of both, it is apparent that an increase in lean mass is seen to a greater extent in ZH fed cattle as opposed to cattle fed ractopamine hydrochloride (Avendano-Reyes et al. 2006).

Warner-Bratzler Shear Force. Shear force values of strip loin steaks were significantly lower for control animals as compared to ZH treated animals at 7 (3.84 kg vs. 4.65 kg) (*P* < 0.001), 14 (3.44 kg vs. 4.18 kg) (*P* < 0.001), and 21 (3.18 kg vs. 3.61 kg) (*P* = 0.003) d aging. At 7 d of aging, 17.44% of the control steaks exceeded the threshold for tender qualification and were considered intermediate/tough, as compared to 46.15% of the ZH steaks that were intermediate/tough. Much like the results in this study, increased WBS of steaks from animals supplemented with β-AA is commonly reported, as several studies have found that numerous β-AA's including ZH increase WBS values (Schroeder el al, 2003; Hilton el al, 2009).

In conclusion, the repartitioning agent zilpaterol hydrochloride, when fed 20 d prior to slaughter, increased carcass weights and yields in beef steers which led to an increase in wholesale carcass lean. Warner Bratzler shear force values are increased with ZH supplementation, however, with appropriate aging, these values can be reduced. Also, extended withdrawal time had no negative impacts on ZH effects within the carcass.

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