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Effect of feeding zilpaterol hydrochloride to beef and calf-fed Holstein cattle on consumer palatability ratings[1]

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ABSTRACT: The need to provide consumer data for beef steak tenderness, juiciness, flavor, and overall palatability ratings from zilpaterol hydrochloride (ZH) beef to the processor, retailers, restaurants, and consumers is paramount. Consumer palatability responses were studied for 14- and 21-d aged USDA Choice and USDA Select quality grade beef and USDA Choice calf-fed Holstein New York Strip steaks from cattle that had been fed ZH for 0, 20, and 30 d before slaughter. Strip loins were cut into 2.54-cm-thick New York strip steaks and assigned to a 14- or 21-d aging treatment. The first and fourth steaks were assigned for 14- or 21-d WBSF analysis, and the second, third, fifth, and sixth steaks were reserved for consumer sensory panel evaluation. Warner-Bratzler shear force (WBSF) analysis was conducted at Texas Tech University (TTU, Lubbock), Kansas State University (Manhattan), Oklahoma State University (Stillwater), and West Texas A&M University (Canyon) with values used to sort steaks for consumer evaluation. Slice shear force analysis was performed at TTU on available paired consumer steaks. Consumers (n = 3,007) in 4 metropolitan areas (Baltimore, MD/Washington, DC; Chicago, IL; Los Angeles, CA; and Lubbock, TX) were asked to rate tenderness, juiciness, flavor, and overall acceptability. Consumers were selected to represent a wide range of income, education, and ethnicity at each city. Steaks were cooked to a medium degree of doneness (71°C), cut into 1 cm^3 pieces, and served warm to consumers. Consumers tasted samples from each of 3 separate steaks from each ZH treatment (0, 20, and 30 d) and within each USDA quality grade and within the 14- and 21-d aging treatments. Steaks were selected to represent the distribution of tenderness for the first, second, and third SD either side of the mean for each treatment. A second calf-fed Holstein consumer study (n = 240) was conducted with consumers eating USDA Choice 14- and 21-d aged steaks from Holstein cattle fed ZH for 0 or 20 d. Steaks from 0- and 20-d ZH treatments were different for tenderness for the 14-d aged USDA Choice and the calf-fed Holstein study groups. No differences were shown for all other 0- and 20-d ZH treatments for tenderness. The 21-d aged USDA Select steaks were improved with aging, which aided in removing the effects of ZH treatment. The ZH treatment of 30 d before slaughter resulted in increased WBSF values and decreased consumer tenderness, juiciness, and overall palatability ratings for 14-d-aged USDA Choice. No differences were shown for tenderness, juiciness, flavor, and overall palatability consumer ratings for 0- and 20-d steaks from 21-d Choice and 14- and 21-d Select quality and aging periods. Overall, USDA Choice Holstein steaks aged 14 and 21 d had differences in tenderness with ZH.

Key words: beef, consumer, dairy, palatability, zilpaterol hydrochloride

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INTRODUCTION

Consumers declare tenderness to be an important factor in their eating experience when consuming beef (Miller et al., 2001). Luño et al. (1999) reported heifers supplemented with clenbuterol had a 34% decrease in initial tenderness and a 38% decrease in overall tenderness by trained panelists. Trained sensory panel results showed a significant difference between clenbuterol and control treatments, which paralleled the Warner-Bratzler shear force (**WBSF**) increase of more than 113%. Schroeder et al. (2003a) reported ractopamine caused a 5% decrease in tenderness initially, whereas the sustained tenderness decreased 6%. The decrease in tenderness for ractopamine was also described by Strydom et al. (2002).

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Sensory panels have shown a decrease in tenderness when zilpaterol hydrochloride (**ZH**) is supplemented. Strydom et al. (1998) reported a decrease of 19% in initial and 15% in sustained tenderness with a 45-d ZH treatment. Leheska et al. (2009) reported a difference of 11% in overall tenderness of control steaks over ZH. Similarly, this decrease in tenderness was reported by Hilton et al. (2009), with a 13% decrease in trained tenderness scores and a 4% decrease in consumer tenderness scores due to ZH treatment. However, Hilton et al. (2009) reported that even with the decreased tenderness ratings by consumers, there were no differences in consumer overall acceptability or tenderness acceptability between controls and ZH beef steaks. Toughness of steaks increased with ZH, but the increase did not affect overall tenderness and overall acceptability ratings (Hilton et al., 2009).

The increase in WBSF values in previous research and the lack of a detrimental impact on consumer acceptability ratings have resulted in the need to determine if consumers can detect differences in the palatability of beef from cattle fed ZH. Therefore, the objectives of the present study were to evaluate consumer palatability responses for 14- and 21-d aged USDA Choice and Select quality grade beef New York Strip steaks and 14- and 21-d aged USDA Choice quality grade New York Strip steaks from calf-fed Holstein cattle fed ZH for 0, 20, and 30 d before slaughter.

MATERIALS AND METHODS

Animal Care and Use Committee approval was not obtained for this study because the samples were obtained from federally inspected slaughter facilities (Cargill, Fiona, TX; JBS Swift, Dumas, TX; National Beef, Liberal, KS; and Tyson, Amarillo, TX).

Beef Selection

Beef in this study came from the New York strip steaks of 4 steer trials and 1 heifer trial (Elam et al., 2009) that were fed ZH for 0, 20, and 30 d before slaughter at a rate of 6.8 g per ton on a 90% DM basis. The cattle were British-cross and Continental-cross breeds and were slaughtered at Cargill Meat Solutions, Tyson Foods, JBS Swift, and National Beef facilities. All steak fabrication, processing, and freezing were conducted at each of 4 laboratories (Texas Tech University, Lubbock; West Texas A&M University, Canyon; Kansas State University, Manhattan; and Oklahoma State University, Stillwater). The USDA Choice and USDA Select (USDA, 1997) strip loins (Institutional Meat Purchase Specification; **IMPS**, #180) were selected (n = 1,180) at each beef processing facility and shipped fresh under refrigerated truck and cut into 2.54-cm-thick steaks, vacuum packaged, boxed, and stored under vacuum-packaged conditions and wet aged at 2°C for 14 and 21 d. The first and fourth steaks were assigned for 14- or 21-d WBSF analysis, and the second, third, fifth, and sixth steaks were paired and reserved for consumer sensory panel evaluation. Paired steaks were frozen at −20°C on their end-point aging day (14 or 21 d) and stored until time of analysis. Warner-Bratzler shear force analysis was then conducted at Texas Tech University, Kansas State University, Oklahoma State University, and West Texas A&M University. Steaks were thawed slowly in a 2°C cooler for 18 to 24 h and cooked on a George Foreman 4 steak grill to an internal steak temperature of 71°C following the protocol in the AMSA sensory guidelines (AMSA, 1995). Temperature was monitored with a digital meat thermometer. Six 1.3-cm diameter round cores were removed parallel to the orientation of the muscle fibers from each LM steak and sheared once using a Salter WBSF machine (G-R Elec. Mfg. Co., Manhattan, KS). The 6 shear force determinations for each steak were then averaged for statistical analysis. Once all the WBSF analyses were complete, all remaining steaks were packaged in ice chest coolers and shipped by overnight transport under dry ice frozen storage to the Texas Tech University Gordon W. Davis Meat Science Laboratory where they were placed in a −20°C freezer until selection for the consumer study. Steaks for the consumer study were selected from the 14- and 21-d aged steaks from the cattle treated with ZH for 0, 20, and 30 d. The steaks were chosen to represent the range in WBSF values of each treatment group (i.e., 14-d CH 0) with 66% of the steaks (n = 779) within ±1 SD, 29% of the steaks (n = 342) between the ±1 and ±2 SD of the mean, and 5% of the steaks (n = 59) were between ±2 and ±3 SD of the mean. Table 1 illustrates the mean WBSF values and the SD within a treatment group. Once steaks were selected for the consumer study, the adjacent paired steaks were subjected to slice shear force (**SSF**) analysis at Texas Tech University. Slice shear steaks were cooked to an internal temperature of 71°C; SSF analysis was performed on 3 different locations across each steak; and an average SSF value was obtained. Slice shear force values were obtained by removing a 1-cm-thick, 5-cm-long slice from the lateral (section A), middle (section B), and medial (section C) ends of each steak and sheared using a United testing instrument (United Calibration Corp and United Testing Systems Inc., Huntington Beach, CA) with a cross head speed of 500 mm/min and a load cell of 50 kg.

Sensory Analysis

The consumer study was conducted in 3 geographic regions of the United States, including east coast, west coast, and central. The United States city that was chosen from the west coast region was Los Angeles, CA; the east coast region was the Baltimore, MD/Washington DC metropolitan area; and the central region was Chicago, IL, and Lubbock, TX. The cities that were chosen for this study represent a balanced population

with diversity of age, ethnic backgrounds, income, and education levels. The cities represent a cross-section of the population for each region of the United States. The USDA quality grade and postmortem aging periods were combined for the study to create 4 separate treatment groups within each city for statistical design. In each city, at least 90 consumers were fed each treatment group (treatment group 1 being the 14-d aged USDA Choice with 1 sample each from the ZH 0-, 20-, and 30-d duration being fed to each consumer; treatment group 2 being the 21-d aged USDA Choice with 1 sample each from the ZH 0-, 20-, and 30-d duration; treatment group 3 being the 14-d aged USDA Select with 1 sample each from the ZH 0-, 20-, and 30-d duration; treatment group 4 being the 21-d USDA Select with 1 sample each from the 0-, 20-, and 30-d duration) for a total of 360 consumers per city selected to represent high, middle, and low income levels. All steaks were thawed over a 24-h period at 2°C and cooked on George Foreman (Original Next Grilleration, model GRP99, George Foreman, Westmont, NJ) grills to medium degree of doneness (71°C). A single consumer was fed three 1-cm^3 pieces of steak representing a 0-, 20-, and 30-d ZH treatment group within a USDA quality grade and aging combination. Consumers were asked to evaluate the steaks using an 8-point hedonic scale for tenderness, juiciness, flavor, and overall liking. Each consumer was also asked to fill out a demographic form, which included information about beef consumption, age, sex, ethnicity, annual income, education level, and beef palatability factors (Figure 1).

An additional group of consumers were fed in Lubbock, TX, at the Texas Tech University Animal and Food Sciences building using the same survey form from the 4 cities for the overall combined study (n = 3,007). All consumers consumed samples of USDA Choice or USDA Select steaks that were aged 14 or 21 d of known WBSF values.

Calf-Fed Holstein Cattle Study

A second consumer study using a separate group of consumers from Lubbock, TX, and Los Angeles, CA, was performed to determine the impact of ZH feeding to calf-fed Holsteins on beef tenderness. The USDA Choice strip loins (LM; IMPS #180, n = 120) from calf-fed Holstein cattle from 2 ZH trials that were aged for 14 or 21 d were fed to a total of 60 consumers evaluated each aging treatment group in each city (n = 240). The USDA Choice steaks were the only quality grade tested because very few of the Holsteins graded USDA Select and did not create a study population.

Statistical Analysis

Consumer data were analyzed used a randomized block design with geographic location being a random effect. The individual consumers were the blocks, and the main effects were aging time by ZH treatment for

Table 1. Warner-Bratzler shear force ranges for 14- and 21-d aged USDA Choice and Select New York strip beef steak selection[1]

Zilpaterol treatment	USDA Choice							USDA Select						
	Mean	+1σ	−1σ	−2σ	+2σ	−3σ	+3σ	Mean	+1σ	−1σ	−2σ	+2σ	−3σ	+3σ
Steaks aged 14 d														
0 d	3.12	4.02	2.23	1.33	4.91	0.43	5.81	3.30	4.10	2.50	1.70	4.90	0.90	5.70
20 d	3.76	4.66	2.85	1.95	5.57	1.05	6.47	3.82	4.67	2.97	2.13	5.52	1.28	6.37
30 d	3.77	4.76	2.79	1.80	5.75	0.81	6.74	4.33	5.65	3.01	1.69	6.97	0.37	8.29
Steaks aged 21 d														
0 d	2.99	3.69	2.29	1.59	4.39	0.89	5.09	3.06	3.89	2.22	1.39	4.73	0.56	5.56
20 d	3.31	4.19	2.41	1.52	5.08	0.63	5.97	3.52	4.41	2.63	1.73	5.30	0.84	6.19
30 d	3.53	4.53	2.53	1.52	5.54	0.52	6.54	3.94	5.05	2.83	1.73	6.16	0.62	7.27

[1]σ = SD. Calf-fed Holstein steaks not included.

each sensory attribute. Statistical analysis was conducted using the MIXED procedure with means within a treatment groups for consumer beef and calf-fed Holstein comparisons and separated by least squares means Student's *t*-test at a significance level of $P < 0.05$ (SAS Inst. Inc., Cary, NC). Analyses were conducted within the 4 study groups and not across USDA quality grade and aging treatments.

RESULTS

Beef Consumer

Behrends et al. (2005) and Felderhoff et al. (2007) observed flavor to be the most important palatability characteristic to consumer acceptability. Neely et al. (1998) found flavor to be just as important as tenderness in determining overall liking in beef consumer panels and that consumer perception of flavor in beef steaks is directly related to the amount of marbling present in the steak. Thus, the average marbling scores for each treatment have been added to the tables to better explain the differences that occurred between treatments. A difference ($P < 0.05$) was shown for the 14-d aged USDA Choice steaks. Consumers observed a difference ($P < 0.05$) between the control (0 d) steaks and 20- and 30-d ZH steaks for the attributes of tenderness, juiciness, and overall liking (Table 2). The differences for the sensory changes may be explained by the difference in average WBSF and SSF values for the treatment groups. An observed increase ($P < 0.05$) of 0.64 and 0.65 kg difference in WBSF values between the control group and the ZH-treated steaks was shown. Based on the SSF averages, there was an observed 3.19 and 3.60 kg increase ($P < 0.05$) in SSF values from the control steaks to the 20- and 30-d ZH-fed steaks. Marbling scores for the steaks that were fed to the consumers indicated that the treatment groups were not significantly different ($P > 0.05$; Table 2). On average, all of the treatment groups fell into the quality grade of USDA Low Choice or a marbling score of Small. Each steak represented 10 consumers, and the control and 20-d ZH steaks had an equal representation of steaks that were USDA High and Average Choice quality grades.

The USDA Select quality grade steaks that were aged for 14 d indicated no differences for all palatability traits (juiciness, tenderness, flavor, and overall palatability; $P > 0.05$) for the control and 20-d ZH treated steaks as shown in Table 3. The steaks from the control group were different from the 30-d fed ZH steaks for tenderness, juiciness, and overall liking. No differences ($P > 0.05$) were observed between the treatment groups for USDA marbling scores. However, differences ($P < 0.05$) were shown for the WBSF and SSF values between the 0, 20, and 30 d treatment groups because the increased duration of feeding ZH increased WBSF and SSF values. The consumers did not detect ($P > 0.05$) the differences in WBSF observed between the control and 20-d steaks, but the consumers did observe the differences ($P < 0.05$) between the control and the 30-d steaks for tenderness.

No differences ($P > 0.05$) occurred for all consumer sensory attributes between the 0- and 20-d duration treatment groups for the USDA Select 14- and 21-d aging groups and the Choice 21-d aged USDA Choice quality grade steaks (Table 4). The means shown in Table 4 for 21-d aged USDA Choice quality grade steaks were different ($P < 0.05$) between the control and 30-d ZH steaks for the tenderness, juiciness, and overall liking attributes. No differences ($P > 0.05$) were observed for flavor between the 0-, 20-, and 30-d treatment groups. Reduced variation in the WBSF values was shown in this study group when compared with the other 3 study groups, which may explain the narrower ranges of the consumer means for all the attributes in the 21-d USDA Choice (Table 4). Results indicate that increased aging of the steaks for longer time periods allowed for less of an impact from ZH.

The 21-d aged USDA Select quality grade study group indicated no significant differences ($P < 0.05$) existed between the 0-, 20-, and 30-d treatments, as shown in Table 5. A linear increase ($P < 0.05$) existed for WBSF and SSF values of 20- and 30-d ZH treated streaks; however, the consumers did not find significant differences ($P > 0.05$) in tenderness, juiciness, flavor, or overall liking. The two 21-d aging treatment groups for the USDA Choice and USDA Select grades show that although there were significant differences ($P < 0.05$) in the treatments for WBSF and SSF values, the consumers did not find the differences ($P > 0.05$) in the control and 20-d Choice and 20- and 30-d Select fed ZH, but did find differences ($P < 0.05$) for the 30-d ZH steaks in the USDA Choice quality grade.

Calf-Fed Holstein Consumer

Table 6 illustrates the calf-fed Holstein consumer data that were obtained on the 14-d aged steaks. In this treatment group the control was significantly ($P < 0.001$) greater than the 20-d and 30-d ZH steaks for tenderness, juiciness, flavor, and overall acceptability. The data in this treatment group are unique in that consumers did not identify the same differences observed in WBSF values among the treatments. Instead, the 20-d fed ZH steaks were found to be significantly ($P < 0.001$) less tender than the 30-d fed steaks and the least performing steak across all sensory attributes. It should be noted that all 3 treatments were considered in the tender range for WBSF values (Miller et al., 2001). The result was the only treatment group in the entire study that did not follow the trend of consumer ratings decreasing as days on ZH increased. Another interesting note from this data set is that the average marbling scores for each treatment were significantly ($P < 0.001$) less as treatment increased. Therefore, not only was the trend observed in the beef studies not seen here, but the consumers did not identify the marbling differences either.

Consumer Sensory Evaluation Survey Form

Tenderness

Please indicate how much you like or dislike the ***Tenderness*** of each sample by placing a check in the appropriate box for each sample.

Extremely Tough	Very Tough	Moderately Tough	Slightly Tough	Slightly Tender	Moderately Tender	Very Tender	Extremely Tender
☐	☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7	8

Is the tenderness Acceptable? **Yes ___** **No ___**

Juiciness

Please indicate how much you like or dislike the ***Juiciness*** of each sample by placing a check in the appropriate box for each sample.

Extremely Dry	Very Dry	Moderately Dry	Slightly Dry	Slightly Juicy	Moderately Juicy	Very Juicy	Extremely Juicy
☐	☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7	8

Flavor

Please indicate how much you like or dislike the ***Flavor*** (all factors included) of each sample by placing a check in the appropriate box for each sample.

Extremely Unbeef-like	Very Unbeef-like	Moderately Unbeef-like	Slightly Unbeef-like	Slightly Beef-like	Moderately Beef-like	Very Beef-like	Extremely Beef-like
☐	☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7	8

Overall Liking of the Samples

Please indicate how much you ***like or dislike*** the sample by placing a check in the appropriate box for each sample.

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Like Slightly	Like Moderately	Like Very Much	Like Extremely
☐	☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7	8

Is this Steak Acceptable? **Yes ___** **No ___**

Figure 1. Consumer sensory evaluation survey form.

About Yourself

(Please circle the answer that applies for each item.)

Gender	Household Size	Household	Age	Ethnic Origin
Male	1 person	Single Income	Under 18	African-American
Female	2 people	Dual Income	18-34	Caucasian/White
	3 people		35-50	Native American
	4 people		Over 50	Hispanic
	5 people			Asian
	6 people			Other
	Over 6 people			

Annual Household Income (if you are a full time student indicate your parent's income)

Under $20,000 $20,000 - $29,999 $30,000 to $49,999 $50,000 - $69,999

$70,000 - $100,000 more than $100,000

Education Level

Non-high School graduate

High school graduate

Some College/Technical School

College graduate

Post graduate

How many times a week do you consume beef?

None

1 to 2

3 to 4

5 to 6

7 or more

What factor of beef palatability is most important?

__ Juiciness

__Tenderness

__ Flavor

Figure 1 (Continued). Consumer sensory evaluation survey form.

The 21-d aged calf-fed Holstein steak consumer data are presented in Table 7. The data follow the same trend as the beef data and not the 14-d aged calf-fed Holstein steaks, where consumer ratings decreased as the days on ZH increased. This decreasing trend is seen for tenderness, juiciness, flavor, and overall liking. In this case, the control is significantly ($P < 0.05$) greater in all categories than the 30-d treatment, and the 20-d ZH is significantly ($P < 0.05$) greater than the 30-d. The results follow closely with the objective data that were compiled on the strip loins before consumer data were obtained.

DISCUSSION

The results from the 21-d USDA Select treatment group were similar to those reported by Hilton et al. (2009) because there were no significant differences observed for beef flavor, juiciness, or overall quality of steaks from cattle fed ZH for the control 20- and 30-d

Table 2. Consumer sensory panel averages for 14-d aged USDA Choice New York strip steaks from control and zilpaterol hydrochloride-treated cattle[1]

	Zilpaterol treatment, d				
Item	0	20	30	*P*-value	SEM[2]
USDA marbling score	Small 80[a]	Small 70[a]	Small 50[a]	0.62	1.12
WBSF,[3] kg	3.12[a]	3.76[b]	3.77[b]	<0.001	0.06
SSF,[3] kg	13.89[a]	17.08[b]	17.49[b]	<0.001	0.28
Sensory attribute					
Tenderness[4]	5.48[a]	4.93[b]	4.66[b]	0.001	0.13
Juiciness[4]	5.39[a]	5.03[b]	4.83[b]	0.002	0.13
Flavor[4]	5.80[a]	5.71[a]	5.52[a]	0.054	0.10
Overall[4]	5.60[a]	5.30[b]	5.06[b]	0.002	0.13

[a,b]Within a row, means without a common superscript letter differ ($P < 0.05$).
[1]n = 734 consumers.
[2]Standard error of the least squares means.
[3]WBSF = Warner-Bratzler shear force; SSF = slice shear force.
[4]1 = extremely tough, extremely dry, extremely unbeef-like, dislike extremely; 8 = extremely tender, extremely juicy, extremely beef-like, like extremely.

treatments. A significant difference in tenderness was shown for the 14-d aged Choice treatment because it decreased by 0.25 on average on the treated steaks. The tenderness difference can also be observed because there was a decrease of 0.28 on the average from the control group to the 30-d treatment.

Juiciness ratings have been shown to be directly linked to degree of doneness (Behrends et al., 2005). Therefore, if juiciness is at an acceptable level then tenderness and flavor will be the most important traits for determination of overall liking. Consumer preferences in degree of doneness can greatly affect the acceptability of juiciness, which is why all of the steaks in the consumer studies were cooked to an equal degree of doneness (Behrends et al., 2005). β-Agonists have shown an overall tendency to slightly decrease juiciness scores of trained and consumer panelists (Schroeder et al., 2003a; Leheska et al., 2009). The trend of slightly decreasing the juiciness scores is also evident in the current study. In the 14-d USDA Choice treatment group there was a significant difference between the control and treatment groups for juiciness. The 14-d USDA Select and 21-d USDA Choice treatment groups had significant differences for juiciness for the control and 30-d ZH, but not for 20-d treatment and control. No differences occurred across the 21-d USDA Select treatment groups for juiciness.

Luño et al. (1999) observed a 20% decrease in juiciness ratings for consumer panel scores when cattle were supplemented with clenbuterol. Strydom et al. (1998) reported similar results in ZH-treated animals, having a 15% reduction in juiciness. Hilton et al. (2009) observed a 3% reduction in juiciness ratings for consumer evaluations when fed ZH, and Leheska et al. (2009) reported similar results, showing a 7% decrease in trained sensory panel scores for juiciness. Leheska et al. (2009) attributed the decrease in juiciness ratings to the decreased amount of intramuscular fat that is deposited

Table 3. Consumer sensory panel averages for 14-d aged USDA Select New York strip steaks from control and zilpaterol hydrochloride-treated cattle[1]

	Zilpaterol treatment, d				
Item	0	20	30	*P*-value	SEM[2]
USDA marbling score	Slight 50[a]	Slight 50[a]	Slight 60[a]	0.71	0.44
WBSF,[3] kg	3.30[a]	3.82[b]	4.33[c]	<0.001	0.07
SSF,[3] kg	15.44[a]	17.97[b]	19.01[b]	<0.001	0.28
Sensory attribute					
Tenderness[4]	5.21[a]	4.95[ab]	4.62[b]	0.04	0.14
Juiciness[4]	5.00[a]	4.89[a]	4.65[a]	0.08	0.12
Flavor[4]	5.67[a]	5.57[a]	5.46[a]	0.10	0.08
Overall[4]	5.29[a]	5.19[a]	4.94[a]	0.08	0.12

[a–c]Within a row, means without a common superscript letter differ ($P < 0.05$).
[1]n = 739 consumers.
[2]Standard error of the least squares means.
[3]WBSF = Warner-Bratzler shear force; SSF = slice shear force.
[4]1 = extremely tough, extremely dry, extremely unbeef-like, dislike extremely; 8 = extremely tender, extremely juicy, extremely beef-like, like extremely.

Table 4. Consumer sensory panel averages for 21-d aged USDA Choice New York strip steaks from control and zilpaterol hydrochloride-treated cattle[1]

	Zilpaterol treatment, d				
Item	0	20	30	*P*-value	SEM[2]
USDA marbling score	Small 80[a]	Small 70[a]	Small 50[a]	0.62	1.12
WBSF,[3] kg	2.98[a]	3.31[b]	3.53[c]	<0.001	0.06
SSF,[3] kg	13.22[a]	14.78[b]	15.44[b]	0.02	0.23
Sensory attribute					
Tenderness[4]	5.49[a]	5.15[ab]	4.87[b]	0.02	0.10
Juiciness[4]	5.24[a]	5.15[a]	4.76[a]	0.06	0.10
Flavor[4]	5.98[a]	5.93[a]	5.81[a]	0.21	0.13
Overall[4]	5.64[a]	5.44[ab]	5.27[b]	0.04	0.22

[a–c]Within a row, means without a common superscript letter differ ($P < 0.05$).
[1]n = 768 consumers.
[2]Standard error of the least squares means.
[3]WBSF = Warner-Bratzler shear force; SSF = slice shear force.
[4]1 = extremely tough, extremely dry, extremely unbeef-like, dislike extremely; 8 = extremely tender, extremely juicy, extremely beef-like, like extremely.

in cattle fed β-agonists. Although minor differences were seen in juiciness, proper management and cooking can control differences (Behrends et al., 2005).

Flavor has been shown to be directly correlated with overall liking of the product when tenderness and juiciness are in an acceptable range (Behrends et al., 2005). Behrends et al. (2005) and Felderhoff et al. (2007) both observed flavor to be the most important palatability characteristic to consumer acceptability. Neely et al. (1998) found flavor to be just as important as tenderness in determining overall liking in beef consumer panels and that consumer perception of flavor in beef steaks is directly related to the amount of marbling present in the steak. The amount of intramuscular fat and juiciness of the steak is therefore directly related to flavor ratings (Neely et al., 1998). Decreasing the amount of intramuscular fat within a steak by the feeding of β-agonists should then result in reduced flavor scores. The effect of reduced intramuscular fat resulting in reduced consumer flavor scores is illustrated by Hilton et al. (2009). The reduced percentage of fat or dilution was related to a 6% decrease in consumer beef flavor ratings. Leheska et al. (2009) also discovered a 3% decrease in trained sensory panel flavor ratings, when cattle were treated with ZH. The impact of ZH on juiciness and flavor was not observed in the current study because the steaks were compared within a USDA quality grade. The fat and moisture contents among the steaks from the treatments were the same, and consumers were not able to find differences in these traits. In the 14-d USDA Choice and USDA Select, there was an observed statistical difference in the control and 30-d ZH-fed steaks that may be accounted for by selection of carcasses that were from the same USDA quality grade. However, in the calf-fed Holstein 21-d aged steaks, there were significant differences observed in the average marbling scores and the flavor ratings from consumers. These results are similar to those observed in the previous studies (Hilton et al., 2009; Leheska et al., 2009). The results from all 3 stud-

Table 5. Consumer sensory panel averages for 21-d aged USDA Select New York strip steaks from control and zilpaterol hydrochloride-treated cattle[1]

	Zilpaterol treatment, d				
Item	0	20	30	*P*-value	SEM[2]
USDA marbling score	Slight 50[a]	Slight 50[a]	Slight 60[a]	0.71	0.44
WBSF,[3] kg	3.06[a]	3.52[b]	3.94[c]	<0.001	0.06
SSF,[3] kg	13.50[a]	15.44[b]	16.61[c]	0.001	0.23
Sensory attribute					
Tenderness[4]	4.99[a]	4.79[a]	4.71[a]	0.48	0.21
Juiciness[4]	4.85[a]	4.81[a]	4.81[a]	0.97	0.24
Flavor[4]	5.61[a]	5.61[a]	5.57[a]	0.91	0.11
Overall[4]	4.90[a]	4.82[a]	4.74[a]	0.53	0.32

[a–c]Within a row, means without a common superscript letter differ ($P < 0.05$).
[1]n = 766 consumers.
[2]Standard error of the least squares means.
[3]WBSF = Warner-Bratzler shear force; SSF = slice shear force.
[4]1 = extremely tough, extremely dry, extremely unbeef-like, dislike extremely; 8 = extremely tender, extremely juicy, extremely beef-like, like extremely.

Table 6. Consumer sensory panel averages for calf-fed Holstein 14-d aged USDA Choice New York strip steaks from control and zilpaterol hydrochloride-treated cattle[1]

	Zilpaterol treatment, d				
Item	0	20	30	*P*-value	SEM[2]
USDA marbling score	Modest 20[a]	Small 80[b]	Small 50[c]	0.01	2.23
WBSF,[3] kg	2.57[a]	3.66[b]	3.70[b]	<0.001	0.13
SSF,[3] kg	12.97[a]	14.58[b]	14.31[b]	0.01	0.41
Sensory attribute					
Tenderness[4]	6.08[a]	4.95[b]	5.38[b]	<0.001	0.16
Juiciness[4]	5.43[a]	4.73[b]	5.01[ab]	0.034	0.23
Flavor[4]	6.25[a]	5.75[b]	5.82[b]	0.027	0.25
Overall[4]	5.96[a]	5.29[b]	5.46[b]	0.007	0.17

[a–c]Within a row, means without a common superscript letter differ ($P < 0.05$).
[1]n = 120 consumers.
[2]Standard error of the least squares means.
[3]WBSF = Warner-Bratzler shear force; SSF = slice shear force.
[4]1 = extremely tough, extremely dry, extremely unbeef-like, dislike extremely; 8 = extremely tender, extremely juicy, extremely beef-like, like extremely.

ies agree that reducing USDA Quality grade and marbling scores results in a decrease of the consumer juiciness and flavor scores.

The effect of β-agonists on meat quality and consumer sensory evaluation has not been extensively researched or fully explained. β-Agonists are generally thought to have major effects on meat quality and composition and are known to increase percent protein and decrease fat content over the carcass. Although ZH increased WBSF values in the previous study and in the current study, the increases had minimal effects on consumer threshold limits for tenderness.

In conclusion, based on the findings of this beef steak consumer study, there were no significant differences observed in sensory attributes between control and 20-d ZH-fed steaks in 3 (USDA Choice 21-d aging and USDA Select 14- and 21-d aging) of the 4 beef treatment groups. The only treatment groups that had a difference in the 0- and 20-d treatment groups were the 14-d aged USDA Choice and the calf-fed Holstein study groups. The differences in tenderness may be explained by the larger difference observed in shear force values between the 0- and 20-d ZH steaks in this treatment group when compared with the other groups. Steaks from animals fed ZH still show a linear decrease in shear force as time of aging increases, and this finding has not been shown in research studies with other β-agonists. In the 21-d aged USDA Select steaks, it appears that aging the steaks aided in removing any significant effect from treatment shown in the 14-d aged USDA Select steaks. Consumer sensory differences were observed in the present study, but the impact of improved tenderness with longer aging postmortem should aid the beef industry in determining the acceptable duration for feeding ZH to cattle before slaughter. The application of 20 d of ZH to beef cattle feed should result in no differences in consumer palatability ratings if the beef is aged for at least 21 d before consumption by the con-

Table 7. Consumer sensory panel averages for calf-fed Holstein 21-d aged USDA Choice New York strip steaks from control and zilpaterol hydrochloride-treated cattle[1]

	Zilpaterol treatment, d				
Item	0	20	30	*P*-value	SEM[2]
USDA marbling score	Modest 20[a]	Small 80[b]	Small 50[c]	0.01	2.23
WBSF,[3] kg	2.46[a]	2.97[b]	2.97[b]	0.03	0.08
SSF,[3] kg	11.10[a]	12.27[b]	13.12[c]	<0.001	0.31
Sensory attribute					
Tenderness[4]	5.83[a]	5.38[ab]	5.12[b]	0.036	0.33
Juiciness[4]	5.40[a]	5.13[a]	4.81[a]	0.165	0.30
Flavor[4]	5.91[a]	5.83[a]	5.36[a]	0.055	0.27
Overall[4]	5.70[a]	5.61[a]	5.24[a]	0.160	0.41

[a–c]Within a row, means without a common superscript letter differ ($P < 0.05$).
[1]n = 120 consumers.
[2]Standard error of the least squares means.
[3]WBSF = Warner-Bratzler shear force; SSF = slice shear force.
[4]1 = extremely tough, extremely dry, extremely unbeef-like, dislike extremely; 8 = extremely tender, extremely juicy, extremely beef-like, like extremely.

sumer. Based on the data from this study, it would be beneficial for the beef industry to use ZH for a duration of no more than 20 d to protect consumer palatability.

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