

Carcass traits and consumer acceptability of striploin steaks from band-castrated, intratesticular zinc-injected, or sexually intact beef cattle¹

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ABSTRACT: One hundred and eighty beef bulls (BW = 337 ± 10.9 kg) were blocked by BW (6 blocks) and assigned randomly to one of three treatments on day 0: 1) INJ; received 1 mL (100 mg Zn) of a Zn solution in each testis, 2) BAN; received blood-restrictive rubber band placed upon the dorsal aspect of the scrotum, and 3) BUL; bulls with testicles remaining intact. Cattle were grouped by weight block in a randomized complete block design (three treatment pens/block and 10 cattle/pen) and harvested by block on three separate dates when blocks reached similar BW and visual subcutaneous fat thickness depth. Striploins were removed from the left carcass sides, vacuum packaged and aged for 14 d, and then frozen at -20 °C. Frozen striploins were sliced into 2.54-cm-thick steaks and remained frozen until analyses. Steaks (*n* = 3/animal) were used to assess consumer acceptability via consumer taste panel (*n* = 152 panelists), Warner-Bratzler shear force, percentage cook loss, and cooked color values. Data were analyzed using mixed model procedures; pen was the experimental unit for all dependent variables. Hot carcass weights and LM area were greater (*P* < 0.01) for the INJ and BUL treatments compared with BAN. Mean yield grade did not differ between treatments

(*P* = 0.12), although BAN carcasses had smaller LM area (*P* < 0.01) than BUL or INJ carcasses. Percentage of USDA Choice or better carcasses was greater (*P* < 0.01) for BAN than INJ and BUL treatments. Consumer panelists detected a difference in perceived tenderness; BAN steaks had greater (*P* = 0.02) tenderness scores than BUL steaks, whereas INJ steaks were intermediate. Panelists rated juiciness of BAN steaks greater (*P* < 0.01) than either BUL or INJ steaks. Panelists rated beef flavor greater (*P* = 0.01) for BAN and BUL steaks than INJ steaks. Overall acceptability was greater (*P* < 0.01) for BAN compared with INJ steaks, whereas BUL steaks were intermediate. Percentage cook loss of striploin steaks (*P* = 0.47) and Warner-Bratzler shear force values (*P* = 0.11) did not differ. Cooked color lightness (*L*^{*}) and redness (*a*^{*}) values were not affected (*P* ≥ 0.23) by treatment. Striploin steaks from BAN and BUL treatments had greater (*P* = 0.02) yellowness values (*b*^{*}) than INJ steaks. The ratio of red-to-brown (630:580 nm) of cooked striploin steaks was greater (*P* = 0.05) for INJ than either BAN or BUL treatments. Carcass and palatability outcomes of INJ were more similar to BUL than BAN, suggesting limited efficacy of INJ in mature beef bulls at feedlot entry.

Key words: beef bulls, carcass traits, castration, consumer taste panel, zinc

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INTRODUCTION

Alternative castration methods are of importance to producers because consumers are increasingly sensitive toward painful animal management practices (Lamb et al., 2016). At present, nearly all male cattle remaining as bulls upon arrival at U.S. feedlots are castrated (92.5%), and of the castrated bulls, the most popular methods are surgical (50.4%) and banding (42.9%), with no reported use of chemical castration (National Animal Health Monitoring System (NAHMS), 2011). Castration reduces animal aggression by eliminating endogenous testosterone and improves meat quality by increasing intramuscular adipose deposition resulting in greater-quality grades and improved tenderness, juiciness, and flavor ratings (Carroll et al., 1975; Calkins et al., 1986). Castration also increases the presence of glycolytic muscle fibers and reduces the frequency of “dark cutting beef” from antemortem stress due to the depletion of muscle glycogen, which reduces the presence of lactic acid resulting in increased muscle pH (Scanga et al., 1998). Castration decreases LM area, G:F, ADG, BW, and HCW compared with bulls; however, the performance reduction in steers is commonly ameliorated by the use of growth promoting implants containing low-dose analogues of testosterone (Price et al., 1980).

Reproductive sterilization utilizing zinc gluconate injection in the testes has been evaluated in companion animals as an alternative to traditional neutering methods (Oliveira et al., 2013); however, zinc injection has been minimally explored in beef cattle as an alternative to traditional castration methods. An injectable product consisting of zinc acetate neutralized by L-histidine (Calviex, Cowboy Animal Health, Plano, TX) has been approved by the FDA for proof-of-concept investigation and food use in beef bulls (Food-use authorization #I-012594-O-002-OT). The objective of this study was to determine the effects of castration (complete removal of scrotum and testicles using a band) and intratesticular zinc injection upon feedlot arrival on carcass traits and consumer acceptability of strip-loin steaks obtained from carcasses of male beef cattle. The authors hypothesized that carcass traits

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and consumer acceptability of bulls injected intratesticularly with zinc would be similar to band-castrated cattle and differ from intact bulls.

MATERIALS AND METHODS

Animal care and use procedures and protocol approval, arrival processing procedures, growth performance, behavior, and serum testosterone and haptoglobin concentration outcomes are previously described in a companion manuscript (Ball et al., 2018). There is no animal care and use protocol associated with the postmortem data reported in this study. The consumer panel protocol used in this study was approved by the Institutional Review Board (#13-05-713) of the University of Arkansas (Fayetteville). Prior to participation, experimental procedures were explained, and a written consent form indicating voluntary participation was obtained from each participant.

The experimental treatments consisted of 1) INJ; received 1 mL (100 mg Zn) of a Zn solution in each testis, 2) BAN; received blood-restrictive rubber band placed upon the dorsal aspect of the scrotum, and 3) BUL; bulls with testicles remaining intact. Body weights were obtained on the day of shipment to feedlot (day -1) and used to determine appropriate BW block allocation to facilitate the randomized complete block design. Blocks ($n = 6$; 30 animals/block; 180 animals total) were constructed by stratification of day -1 BW, arrival date during backgrounding phase, and number of times treated with an antibiotic. The lightest 10 animals within a treatment were allocated to a pen, followed by the 10 next lightest animals, and so on until six pens within each treatment were allocated. Pens within block (three per block) were harvested according to their projected final BW and visual appraisal by trained personnel for market readiness. Blocks 5 and 6 were harvested (USDA Establishment #3, Cactus, TX) on day 155; blocks 3 and 4 were harvested on day 176; blocks 1 and 2 were harvested on day 197. Approximate age of cattle at time of harvest was 14 to 18 mo of age; however, cattle were purchased from auction markets, and exact age and breed of cattle are unknown. Breed of cattle was mixed but predominantly of

Angus origin. Carcasses were evaluated after a 24-h chill period. Harvest floor data, crest height, and lean color score at the 12th rib were recorded by trained personnel (blinded to treatment) from the West Texas A&M University (WTAMU) Beef Carcass Research Center (Canyon, TX). USDA quality and yield grade as well as LM area and 12th rib s.c. fat depth were determined by a vision camera system (VBG 2000; E+V Technology GmbH, Oranienberg, Germany).

Procurement

Approximately 24 h after slaughter, striploins from the left side of each carcass were obtained from the beef processor and transported to the WTAMU Meat Lab, wet aged for 14 d, and then frozen at -20°C . Frozen striploins were transported to the University of Arkansas Red Meat Abattoir and then sliced via bandsaw into 2.54-cm-thick steaks such that a minimum of three steaks were obtained from each striploin. One steak was used for cooking loss, Warner-Bratzler shear force (WBSF), and cooked color; the remaining two steaks were used for a consumer taste panel.

Cooking Loss

Prior to cooking for determination of WBSF, steaks ($n = 120$) were thawed for 24 h at 4°C , blotted dry, and weighed before cooking on a preheated (204°C) electronic countertop griddle (model 0690005; National Presto Industries, Inc., Eau Claire, WI). The steaks used for cooking loss were also used for WBSF; however, only 120 steaks were used for cooking loss, excluding blocks 5 and 6 (mechanical failure), whereas all blocks had steaks represented in other analyses. Steaks were turned every 4 min until they reached an internal temperature of 71°C in the geometric center as determined by a digital thermometer (C28 K Type; Comark Instruments, Beaverton, OR). Steaks were allowed to cool at room temperature (23°C) before being reweighed to calculate cooking loss [$100 - ((\text{cooked weight}/\text{raw weight after thawing}) \times 100)$].

Warner-Bratzler Shear Force

The same steak cooked for cooking loss assessment was used for WBSF after being allowed to cool and weighed. Steaks ($n = 180$) used for the determination of WBSF values as a proxy for tenderness were cooked using the same procedures as previously described, and after cooking and cooling to room temperature (23°C), six 1.27-cm-diameter

cores were removed from each steak parallel to the muscle fiber orientation. Each core was sheared perpendicular to the longitudinal positioning of the muscle fibers in the geometric center of the sample using a WBSF device attached to an Instron Universal Testing Machine (model 4466; Instron Corp., Canton, MA), equipped with a 50-kg load cell and a crosshead speed of 24.9 cm/min. Shear force values (reported in kgF) were the average of six cores from each steak.

Cooked Color

Before WBSF cores were removed, each steak was sliced laterally, and instrumental color (L^* , a^* , b^*) was determined immediately. Cooked color values for each steak were determined from an average of three randomly placed readings with a Hunter MiniScan XE Plus (Hunter Associates Laboratory, Reston, VA) using Illumina A with a 9-mm aperture and a 10° observation angle. Red-to-brown was calculated as the reflectance ratio of 630 to 580 nm (representing the change of denatured myoglobin during cooking to either metmyoglobin or denatured myoglobin). Instrumental cooked color values were used to calculate hue angle (representing a change from the true red axis) as: $\tan^{-1}(b^*/a^*)$ and chroma (representing the total color) as: $(a^{*2} + b^{*2})^{1/2}$. The colorimeter was calibrated against standard black and white tiles before data collection.

Consumer Taste Panel

Consumer panels (15 sessions; 152 panelists) were conducted on a single day at the University of Arkansas Food Science and Sensory Laboratory (Fayetteville, AR). Consumers were screened before panel participation; prerequisites for participation included male or female consumers who consumed beef and liked steak. Each panelist was assigned a random number and instructed to sit at a designated monitor to complete each sample ballot. Panels were conducted with 8 to 12 consumers/session; each session lasted approximately 20 min. Consumer panelists were provided a Styrofoam tray containing a napkin, fork, water, and three saltine crackers. The water and saltine crackers were available to each panelist to cleanse their palette between each sample, and they were instructed to do so prior to consumption of each sample. Steaks were cooked on electronic countertop griddles (model G767; Farberware, Fairfield, CA) and turned every 4 min until an internal end point temperature of

71.1 °C was achieved. Internal temperature was monitored using digital thermometers (model 51 TI Thermometer; Fluke Corp., Everett, WA) placed in the geometric center of each steak. For each session, steaks were cooked and allowed to rest for 3 to 5 min before cutting. Each cooked steak was trimmed of the outside edges, excess muscle, and fat before cutting into 1 cm × 1 cm × cooked steak thickness. Pieces were randomly identified with a three-digit code for assessment and held in a warmer (model MP-941; Henny Penny Corp., Eaton, OH) at 62.8 °C for approximately 10 min during each sensory evaluation session. Samples ($n = 2/\text{treatment}$; total of six samples) were presented to consumer panelists in randomized order, and each panelist evaluated their steak piece at his or her own pace for overall scale (1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly, 5 = neither like nor dislike, 6 = like slightly, 7 = like moderately, 8 = like very much, and 9 = like extremely). A minimum of four panelists evaluated each individual steak. Tests were conducted under fluorescent lights with partitioned booths to isolate panelists. Questions included consumer likeness of tenderness, juiciness, flavor, off-flavor (yes/no), off-flavor score (if off-flavor = yes, then the same 1–9 Likert scale described previously was used), and overall acceptability. The off-flavor indication was dichotomous (yes or no) and was utilized to determine whether consumers detected what they perceived as an off-flavor in the steak samples. Consumers who indicated off-flavor were subsequently asked to indicate their perception of the off-flavor using the previously described Likert scale.

Statistical Analyses

Statistical analyses were conducted for all outcome variables in a randomized complete block design. Data were tested for normality using PROC UNIVARIATE, and nonparametric data were log transformed prior to analysis if normality was improved. If normality was not improved, initial geometric means were utilized. Quantitative carcass and steak variables were analyzed using the mixed model procedure of SAS (Version 9.4; SAS Inst. Inc., Cary, NC) with treatment as the lone fixed effect and block as the random effect. Quantitative consumer taste panel results were averaged across all consumer observations across all steaks from cattle within pen to avoid pseudoreplication due to multiple animals from each pen of multiple consumer observations. Categorical carcass and ordinal scale consumer panel data were analyzed

Table 1. Effect of castration and method of castration on USDA quality and yield grade in male beef cattle

Item	Treatment ¹			P-value
	BAN	BUL	INJ	
Quality grade, %				
Select or standard	44.4 ^b	71.7 ^a	76.1 ^a	<0.01
Choice	55.6 ^a	28.3 ^b	23.9 ^b	<0.01
USDA yield grade, %				
1	1.9	9.4	8.7	0.30
2	27.6 ^b	37.4 ^{ab}	59.1 ^a	0.04
3	51.8 ^a	28.2 ^b	27.7 ^b	0.06
4	17.0	23.1	4.2	0.13

^{a-b}Rows without common letter superscript differ, $P < 0.05$.

¹BAN = bulls that received blood-restrictive rubber band placed upon the dorsal aspect of the scrotum; INJ = bulls that received 1 mL (100 mg Zn) of a Zn solution in each testis; BUL = bulls with testicles remaining intact.

using PROC GLIMMIX of SAS with a binomial error distribution. Pen was the experimental unit for all dependent variables analyzed. Means were separated at an α of 0.05 using the PDIF option in SAS. Statistical significance was declared at $P \leq 0.05$, and tendencies were declared at $0.05 < P \leq 0.10$ for all dependent variables.

RESULTS AND DISCUSSION

Carcass Characteristics

The percentage of cattle grading USDA Choice was greater (Table 1; $P < 0.01$) in BAN (55.6%) than in either BUL (28.3%) or INJ (23.9%). Conversely, the percentage of cattle grading USDA Select or USDA Standard was greater ($P < 0.01$) in BUL (71.7%) and INJ (76.1%) than in BAN (44.4%). No cattle graded USDA Prime nor were there any cattle assigned as “no-rolls.” All cattle were A maturity with no ossification of the thoracic vertebrae and with distinct separation of the sacral vertebrae. Quality grades are assigned by USDA personnel based on marbling and skeletal maturity and can be affected by a multitude of factors including genetics, dietary manipulations, and health. Castration in males increases marbling and therefore quality grade compared with intact bulls due to reduced testosterone concentrations in steers (Field, 1971). No growth implants were used during the present study because the authors hypothesized similar outcomes between BAN and INJ compared with BUL and did not want the effects of exogenous androgens to influence treatment effects. A review by Duckett and Pratt (2014) reported that use of

growth implants reduced marbling scores between 3% and 12% depending on the type of implant and number of times implanted compared with a nonimplanted control. Therefore, had we implanted BAN, their quality grades may have been comparable to BUL and INJ. Conversely, we speculate that BAN would have had performance and feed conversion similar to BUL and INJ had a growth implant regimen been used. As expected, castration via BAN affected quality grade as a function of increased fat deposition compared with INJ and BUL. The intratesticular injection of zinc did not alter quality grade from that of BUL; similar quality grades noted in BUL and INJ are indicative of the limited efficacy in INJ to reduce male characteristics associated in bulls compared with steers. Ball et al. (2018) reported similar testosterone concentrations in INJ and BUL compared with CON; however, they were able to report that INJ was reproductively unviable from histopathological observations.

There were no differences (Table 1; $P = 0.30$) between treatments in the percentage of USDA yield grade 1 carcasses. According to the USDA (2017), only 6.1% of beef carcasses grade USDA 1; therefore, the results in the present study concur as a small percentage of cattle graded USDA 1, which explains the absence of treatment differences for carcasses grading USDA 1. However, the percentage of cattle grading USDA yield grade 2 was greater ($P = 0.04$) for INJ (59.1%) than BAN (27.6%), whereas BUL (37.4%) were intermediate. The increase in percentage of USDA yield grade 2 in INJ compared with BAN is relative to the antagonistic relationship between quality and yield evidenced by the increase in fat thickness and

decrease in LM area in BAN compared with INJ. Intramuscular fat deposition (marbling) is the lowest priority of the four fat depots to occur in cattle: internal, subcutaneous, and intermuscular fat deposition, respectively, occur prior. Hence, cattle with greater marbling often have greater subcutaneous fat, which negatively affects their yield grade. There was a tendency ($P = 0.06$) for the percentage of cattle grading USDA yield grade 3 to be greater for BAN (51.8%) than either BUL (28.2%) or INJ (27.7%), and this observation further characterizes the antagonism between intramuscular and subcutaneous fat deposition. There were no differences ($P = 0.13$) in the percentage of USDA yield grade 4 carcasses; however, it should be noted that only 4.2% of INJ were USDA 4 or 5 compared with BAN (17.0%) or BUL (23.1%) and a larger number of carcasses are probably required to statistically resolve the numerical difference in percentage of carcasses grading USDA 4. It is interesting to note that over 20% of bulls graded USDA 4, which contradicts other studies (Berry et al., 1978) that bulls do not deposit as much subcutaneous fat as steers; thus, bulls have improved (lower) yield grades compared with steers. The authors suggest that the numerically greater number of USDA 4 for BUL is an artifact of small sample size and impacts on this categorical outcome. However, this result is biologically explained by the HCW of BUL being 414 kg and thus requirement of a greater LM area compared with the 366 and 404 kg for BAN and INJ, respectively. No cattle graded USDA 5.

Hot carcass weights were greater for INJ (404 kg) and BUL (414 kg) compared with the BAN (366 kg) treatment (Table 2; $P < 0.01$). In the

Table 2. Effect of castration and method of castration on carcass traits in male beef cattle

Item	Treatment ¹			SEM ²	P-value
	BAN	BUL	INJ		
HCW, kg	366 ^b	414 ^a	404 ^a	3.7	<0.01
Dressed carcass yield, %	60.0	60.4	60.0	0.4	0.72
Marbling score ³	415 ^a	370 ^b	361 ^b	9.3	<0.01
Lean color score ⁴	4.98	5.10	5.00	—	0.19
Fat thickness, cm	1.47	1.37	1.17	0.1	0.17
LM area, cm ²	87.7 ^b	101.3 ^a	98.1 ^a	1.9	<0.01
Yield grade	3.32	3.15	2.81	0.16	0.12
Crest, cm	20.8 ^b	25.1 ^a	25.7 ^a	1.0	0.01

^{a-b}Rows without common letter superscript differ, $P < 0.05$.

¹BAN = bulls that received blood-restrictive rubber band placed upon the dorsal aspect of the scrotum; INJ = bulls that received 1 mL (100 mg Zn) of a Zn solution in each testis; BUL = bulls with testicles remaining intact.

²Pooled SEM.

³300 = Slight⁰⁰; 400 = Small⁰⁰; 500 = Modest⁰⁰.

⁴Lean color score (brightness); 1 = light pink, 2 = pink, 3 = dark pink, 4 = light cherry red, 5 = cherry red, 6 = dark red, 7 = very dark red {1/3 dark cutter}, 8 = maroon {2/3 dark cutter}, 9 = dark maroon {full dark cutter}.

companion manuscript, Ball et al. (2018) reported greater final BW in INJ and BUL compared with BAN. Previous research in chemically (lactic acid) castrated bulls reported that intact bulls had greater HCW compared with chemically castrated cattle (Cohen et al., 1991). Similarities in HCW between INJ and BUL correlates with similarly increased serum testosterone concentrations in INJ and BUL compared with BAN (Ball et al., 2018) and was phenotypically confirmed via noticeably increased male characteristics possessed by both INJ and BUL treatments. Crest height was greater ($P = 0.01$) in BUL (25.1 cm) and INJ (25.7 cm) compared with BAN (20.8 cm). Crest height is a phenotypic indicator of the effects of testosterone; thus, the increase in crest height observed for BUL and INJ compared with BAN was correlated to the difference in testosterone concentrations reported in the companion manuscript (Ball et al., 2018). Dressed carcass yields were not affected ($P = 0.72$) by treatment. Bulls often have greater dressed carcass yields compared with steers due to increased muscling and often steers have greater KPH fat (Champagne et al., 1969). However, that did not occur in the present study, probably due to INJ not causing complete cessation of testicular function as noted by serum testosterone not completely ablated by INJ and all treatments having similar KPH fat; however, the similar fat thickness across all treatments may explain the similar dressed carcass yields between BAN, BUL, and INJ. Marbling scores were greatest in BAN (Small¹⁵) compared to either INJ (Slight⁶¹) or BUL (Slight⁷⁰; $P < 0.01$). The present study differs from Pérez-Linares et al. (2017) where Holstein bulls were immunocastrated (Bopriva, Zoetis) on four different occasions had greater marbling scores than bulls treated with a saline placebo. Lean color scores and fat depth were similar ($P \geq 0.17$) between treatments. All cattle were harvested with similar visual assessment of fat deposition; thus, the similar 12th rib s.c. fat depth was expected. Conversely, LM area was greater ($P < 0.01$) in BUL (101.3 cm²) and INJ (98.1 cm²) than BAN (87.7 cm²). Cohen et al. (1991) reported adjusted LM area of bulls was greater compared to surgical castrates and also greater compared with chemically castrated (lactic acid) cattle in 1 yr of a 2-yr study. Longissimus muscle area is highly correlated to carcass weight (Greiner et al., 2003), which is supported by the present study; however, BAN cattle were not implanted with analogues of testosterone as per standard industry practices, which presumably would have increased both HCW and LM area. Greater LM area in BUL and

INJ corresponds to the increase in serum testosterone concentration in INJ and BUL compared with BAN (Ball et al., 2018), indicative of limited castration efficacy in INJ. Numeric yield grade did not differ ($P = 0.12$) between all treatments. Our carcass variable observations suggest limited efficacy of INJ to reduce male characteristics via castration as indicated by similar characteristics of BUL and INJ compared with BAN.

Consumer Taste Panel

Consumer taste panelists ($n = 152$) were predominantly female (71.7%); age varied from 18 to 24 yr old (8.6%), 25 to 34 yr old (25.8%), 35 to 45 yr old (17.2%), 46 to 54 yr old (23.2%), 55 to 65 yr old (13.3%), and over 65 yr old (11.9%). The majority of panelists (55%) had an annual income less than \$50,000; however, 38.1% earned at least \$60,000 annually, and only 17.2% of panelist earned less than \$20,000 annually. Consumer panelists detected a difference in perceived tenderness; BAN steaks had greater ($P = 0.02$) tenderness than BUL steaks, whereas INJ steaks were intermediate (Table 3). Panelists rated juiciness greater ($P < 0.01$) in BAN steaks than either BUL or INJ steaks. Flavor was liked more ($P = 0.01$) by panelists in BAN and BUL steaks than in INJ steaks. Overall acceptability was greater ($P < 0.01$) for BAN steaks than INJ steaks, whereas BUL steaks were intermediate. Research by Unruh et al. (1987) evaluating the palatability of steers compared with bulls reported that steaks from steers were juicier, more tender, and overall more acceptable compared with bulls, which agrees with the present study. Consumers preferred BAN steaks to INJ and BUL steaks indicative of U.S

Table 3. Effect of castration and method of castration on consumer taste panel outcomes in male beef cattle

Item ¹	Treatment ²			P-value
	BAN	BUL	INJ	
Tenderness	6.68 ^a	6.16 ^b	6.34 ^{ab}	0.02
Juiciness	6.67 ^a	6.01 ^b	6.08 ^b	<0.01
Flavor	6.44 ^a	6.41 ^a	6.02 ^b	0.01
Acceptability	6.53 ^a	6.26 ^{ab}	5.99 ^b	<0.01
Off-flavor, %	17.29 ^b	16.13 ^b	28.46 ^a	<0.01
Off-flavor score	5.27	4.88	4.73	0.35

^{a-b}Rows without common letter superscript differ, $P < 0.05$.

¹Hedonic scale: 1 = dislike extremely to 9 = like extremely.

²BAN = bulls that received blood-restrictive rubber band placed upon the dorsal aspect of the scrotum; INJ = bulls that received 1 mL (100 mg Zn) of a Zn solution in each testis; BUL = bulls with testicles remaining intact.

consumer taste preferences of traditionally castrated beef compared with BUL or INJ, which possessed phenotypic male characteristics. Panelists deemed steaks from INJ to be similar to BUL, whereas BAN was more favorable to consumers for each variable. Consumer detection of off-flavor was greater ($P < 0.01$) in INJ (28.46%) than in either BAN (17.29%) or BUL (16.13%) steaks. The intratesticular injection of zinc negatively affected perceived off-flavor of steak compared with BAN or BUL indicating a potential effect of INJ on steak flavor. Of those panelists that deemed an off-flavor, the likeability of the off-flavor was not different ($P = 0.35$) between treatments. Results from the consumer taste panel indicate a preference for steak from BAN compared with BUL or INJ; however, it should be noted that almost all of the beef consumed in the United States derived from males is from steers; thus, these consumers were unaccustomed to steak from bulls and probably has an effect on their perception of flavor attributes.

Cook Loss and Tenderness

Percentage cook loss of striploin steaks did not differ ($P = 0.47$) between treatments (Table 4). Cooking loss of steaks influences product yield and profitability (Kondjoyan et al., 2013). In agreement with the present study, Costa et al. (2007) reported no differences in cooking loss in steaks from cross-bred (Nelore \times Charolais) steers and bulls, whereas Vaz and Restle (2000) reported similar results in

Hereford bulls and steers. Warner-Bratzler shear force values did not differ ($P = 0.11$) between treatments (BAN = 3.7, BUL = 4.0, and INJ = 3.9 kgF), but numerical differences suggest slight increase in tenderness for BAN. Previous research on immunocastrated bulls concurs with the present study, as several studies have reported no differences in shear force values of beef from *B. taurus* in the feedlot due to castration or method (Cook et al., 2000; Miguel et al., 2014). The threshold of acceptable tenderness (<4.55 kgF) utilized in the present study was based on findings reported by Tatum et al. (1999) and consensus established at the National Beef Tenderness Conference. Treatment did not affect ($P = 0.21$) the percentage of WBSF values less than the threshold (<4.55 kgF) of acceptable tenderness; however, 94.5%, 85.2%, and 81.8% of BAN, INJ, and BUL were less than the tenderness threshold, respectively. Conversely, Costa et al. (2007) reported steers to have significantly improved tenderness values compared with bulls. A larger sample size may be required to statistically resolve the numerical differences in tenderness observed from the present study.

Cooked Color

Cooked color of striploin steaks indicates that lightness values (L^*) were not different ($P = 0.44$) between treatments (Table 4). Intact males typically have lesser L^* values (fresh or cooked color) compared with castrates due to increased pH in

Table 4. Effect of castration and method of castration on cook loss, tenderness, and cooked color in male beef cattle

Item ^{2,3}	Treatment ¹			SEM ⁴	P-value
	BAN	BUL	INJ		
Cook loss, %	22.2	21.2	22.3	0.7	0.47
WBSF ⁵ , kg force	3.7	4.0	3.9	0.1	0.11
WBSF < 4.55 kg force, %	94.5	81.8	85.2	5.0	0.21
L^*	57.5	56.8	57.7	0.5	0.44
a^*	17.1	17.6	16.9	0.3	0.23
b^*	16.8 ^a	16.9 ^a	16.4 ^b	0.1	0.02
Chroma	24.1	24.4	23.7	0.3	0.10
Hue angle	44.7	44.0	44.4	0.5	0.59
Red-to-brown	2.2 ^b	2.2 ^b	2.4 ^a	0.1	0.05

^{a-b}Rows without common letter superscript differ, $P < 0.05$.

¹BAN = bulls that received blood-restrictive rubber band placed upon the dorsal aspect of the scrotum; INJ = bulls that received 1 mL (100 mg Zn) of a Zn solution in each testis; BUL = bulls with testicles remaining intact.

²Cook loss = $100 - [(\text{cooked weight} / \text{raw weight}) \times 100]$; WBSF = mean kgF of 6 cores per steak.

³ L^* = lightness, a^* = redness, b^* = yellowness, chroma = intensity of light, hue angle = distance from true red axis, red-to-brown = spectral ratio of 630:580.

⁴Pooled SEM.

⁵WBSF = Warner-Bratzler shear force.

bulls compared with steers (Page et al., 2001); however, the current observations do not agree with previous research. Redness values (a^*) did not differ ($P = 0.23$) between castration treatments. Yellowness values (b^*) of striploin steaks were greater ($P = 0.02$) for BAN and BUL than INJ. There was a trend for chroma values to be greater ($P = 0.10$) in BUL compared with INJ, whereas BAN was intermediate. There were no differences ($P = 0.59$) in hue angle values of striploin steaks. The ratio of red-to-brown (630:580 nm) of cooked striploin steaks was greater ($P = 0.05$) in INJ compared with either BAN or BUL. Red-to-brown ratio indicates reduced myoglobin denaturation in INJ compared with BAN or BUL. Internal cooked color is highly correlated to muscle pH and myoglobin concentration; greater muscle pH protects myoglobin from denaturation during cooking, which results in an undercooked appearance (Trout, 1989; Hunt et al., 1999).

CONCLUSION

The percentage of cattle grading USDA Choice or better and overall consumer acceptability was increased for BAN compared with INJ, whereas INJ and BUL cattle had greater HCW, LM area, and crest height than BAN. Hence, INJ possessed similar carcass characteristics and consumer acceptability compared with BUL, resulting in disagreement with our hypothesis. Shear force, cooking loss, and instrumental cooked color values were minimally affected by intratesticular zinc injection. The INJ treatment evaluated in the present study may be a viable option for sterilization, but not castration of more mature beef cattle upon feedlot entry because meat quality and consumer acceptability were more similar to BUL than BAN. However, INJ may have value in a natural market setting that does not allow the use of growth implantation, places merit on carcass yield rather than quality, and where sterilization is desirable.

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