Postmortem Injection of Calcium Chloride Effects on Beef Quality Traits[1,2]

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ABSTRACT: Twenty-two *Bos indicus* type steers were commercially slaughtered, and their carcasses were chilled and processed to determine the effects of injecting calcium chloride ($CaCl_2$) on beef steak palatability and quality traits. Top loin and inside round subprimals were removed from each carcass using industry fabrication procedures. No injection (control) or injection of 200 m*M* $CaCl_2$ at 5% (wt/wt) was applied at 30 h postmortem to subprimals from alternating right and left sides. After vacuum storage for 7 d postmortem at 2°C, 2.54-cm thick steaks were cut from each subprimal. Eighty-six percent of the control longissimus lumborum (LL) steaks and 78% of the semimembranosus (SM) control steaks had Warner-Bratzler (WBS) values > 4.5 kg, and the injection of $CaCl_2$ reduced this percentage to 43 and 24%, respectively. The injection of $CaCl_2$ improved ($P < .05$) trained sensory tenderness ratings for both LL and SM, while not affecting ($P > .05$) flavor intensity or causing any off-flavor problems ($P > .05$), compared with the controls. Lean color scores for the LL were not affected ($P > .05$) by the injection of $CaCl_2$, but SM lean color was lighter red ($P < .05$) than controls. Therefore, a 5% (wt/wt) injection of 200 m*M* $CaCl_2$ solution can be applied under commercial conditions to improve beef steak tenderness and reduce tenderness variation without detrimental effects on other palatability or quality traits.

Key Words: Beef, Calcium Chloride, Color, Flavor, Industry, Tenderness

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Introduction

The beef industry is striving to produce a leaner, more consistent product at the demand of retailers and consumers. As the amount of subcutaneous fat is reduced, intermuscular and intramuscular fats are lowered, causing increased variation in meat palatability (Smith et al., 1987). The organoleptic trait most affecting consumer acceptance of beef is inconsistent tenderness (Morgan et al., 1991). Therefore, a commercially applicable method to ensure a consistently tender product is critical for the consumer acceptance of beef. Calcium Chloride ($CaCl_2$) injection or infusion improved or accelerated tenderness in prerigor meat (Koohmaraie et al., 1988, 1989, 1990; Koohmaraie and Shackelford, 1991; Morgan et al., 1991; Wheeler et al., 1991). Wheeler et al. (1992) obtained similar results with postrigor injection, if the meat was aged 7 d postmortem. Wheeler et al. (1993) reported that an injection at 24 h postmortem of a 200 m*M* $CaCl_2$ solution at 5% (wt/wt) reduced the variation in beef tenderness without affecting other beef quality or palatability traits. The development of such a method could be an integral part of reducing the variation in beef tenderness. *Bos indicus* cattle types have shown to be more variable in tenderness and Warner Bratzler Shear Force values than their *Bos tarus* counterparts. Thus, the use of cattle with high *Bos indicus* inheritance in the present study should test the ability of $CaCl_2$ to improve the tenderness of beef steaks. The application of this $CaCl_2$ injection process to ensure beef tenderness in a commercial beef processing facility has not been demonstrated. Therefore, the purpose of this research was to test the efficacy of an injection of $CaCl_2$ into subprimals at 24 h postmortem in a beef slaughter and processing facility.

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Materials and Methods

Twenty-two *Bos indicus* type steers were fed in a commercial feedlot and slaughtered at the Excel, (Plainview, TX) beef processing facility. Steers were selected from one pen from a commercial feedlot and had received the same feeding regimen and implant schedule for 140 d until slaughter.

Carcass Evaluation. After slaughter and a 24-h chill, the carcasses were ribbed between the 12th and 13th ribs and evaluated by two experienced Texas Tech University Meat Science personnel for adjusted fat thickness, hot carcass weight, ribeye area, kidney, pelvic, and heart fat percentage, skeletal and lean maturity, marbling, USDA quality and yield grades, lean color, texture and firmness (Table 1) according to USDA standards(1989).

Fabrication. At 24 h postmortem, the boneless top loin (IMPS #180) and boneless inside rounds (IMPS #168) were fabricated according to the Institutional Meat Purchasing Specifications (IMPS) for fresh beef (USDA, 1990). Subprimal cuts from alternating sides were assigned randomly to either a control (no injection) or 200 m*M* food-grade $CaCl_2$ (Tetra Technologies, The Woodlands, TX) injection at 5% (wt/wt). The injection was performed in the Excel beef processing facility using a multi-needle, Gunther (Model PI 16/32) pickle injector (Hausansechrift, Dieburg, Germany). Tap water (23°C) was used to make the $CaCl_2$ solution and the meat temperature was 2°C. After injection, top loin and inside round cuts were allowed to equilibrate for 5 min, then weighed to determine final percentage of injection (Table 2). All subprimals were labeled by animal number and treatment, vacuum-packaged, boxed, shipped to the Texas Tech University Meat Science Laboratory, and stored at 2°C for 7 d.

At 7 d postmortem, all subprimals were removed from the vacuum packages and purge was weighed. The subprimals were cut into 2.5-cm thick steaks. The longissimus lumborum (**LL**) and semimembranosus (**SM**) from top loin and inside round subprimals, respectively, were evaluated. Two steaks were frozen (−30°C) and shipped to ARS, USDA, Clay Center, NE, for Warner-Bratzler shear (**WBS**) force and trained sensory panel evaluation. A third steak was packaged in a Reynolds (914) oxygen-permeable overwrap package (Richmond, VA), and displayed in a Tyler (model DGC6) retail display case (Tyler refrigeration, Niles, MI) at 2°C under 24 h exposure to 1,615 lux fluorescent light for 5 d. The steaks were evaluated daily for lean color (1 = bleached red, 4 = cherry red, 8 = very dark red) and percentage of discoloration (1 = 0%, 4 = 20 to 59%, 7 = 100%) according to AMSA (1991) using Research Report 336, Standards for Beef Color, New Mexico State University (1977). Two (SM) or three (LL) Minolta colorimeter (model CR-200b, Minolta, Ramsey, NJ) readings at different locations for L*, a*, and B* were collected and averaged on each steak at d 1 through 4 of display.

Shear Force and Sensory Evaluations. Steaks for WBS force determinations were stored at −30°C for 7 to 10 d before thawing 24 h at 3°C. Steaks were broiled on Farberware Open Hearth electric broilers (Farberware, Bronx, NY) to an internal temperature of 70°C. Steaks were turned after reaching 40°C. Internal temperature was monitored in the geometric center of the steak using iron constantan thermocouple wires attached to a Honeywell potentiometer (Scarborough, ON, Canada). Steaks were cut in the center and scored for internal cooked color within 5 min of removal from the heating source according to National Live Stock and Meat Board Beef Steak Color Guide. After cooking, steaks were chilled 24 h at 3°C; then six 1.3-cm diameter cores were removed from each steak parallel to the muscle fiber orientation and sheared once with an Instron model 1132/Microcon II (Instron, Canton, MA) with a WBS attachment. The crosshead speed was 5 cm/min and the fail criterion was 75%.

Steaks for sensory evaluation were cooked as described above. An eight-member trained sensory panel (Cross et al., 1978) evaluated warm 1-cm^3 samples for tenderness, juiciness, flavor intensity, ease of fragmentation, and amount of connective tissue using 8-point scales (8 = extremely tender, juicy, intense, easy and none; 1 = extremely tough, dry, bland, difficult and abundant) and off-flavor using a 4-point scale (4 = none and 1 = intense).

Statistical Analysis. Data were analyzed by ANOVA with GLM procedures of SAS (1985) with two muscles (LL and SM) × two treatments (control with no injection and 200 m*M* calcium chloride injection) and 22 replications. No significant interactions were found for all treatment × muscle interactions, therefore, all data were pooled. Mean separation for a significant ($P < .05$) main effect was accomplished with the probability difference option (a pair-wise *t*-test) of the least squares procedures.

Results and Discussion

The wide range in carcass traits indicated a large amount of variation in the cattle used in this experiment (Table 1). The injection of $CaCl_2$ reduced ($P < .05$) WBS force values in both the LL and SM compared with control steaks (Table 2). The WBS results are in agreement with Wheeler et al. (1993) for LL and SM injected at 24 h postmortem with 200 m*M* $CaCl_2$. However, the reduction in SM was not as large as the reduction reported by Wheeler et al. (1991). The discrepancy in the results may be due to differing concentrations and injection levels of $CaCl_2$ (300 m*M* at 10% vs 200 m*M* at 5%) in the two studies. Of the 86% (LL) and 78% (SM) of the control samples that were rated “tough” (LL and SM >4.5 kg)

Table 1. Means, standard deviations, and ranges for carcass traits

Trait	Mean	SD	Range
Hot carcass wt, kg	312	79.1	260–383
Skeletal maturity[a]	190	55.8	130–370
Lean maturity[a]	180	23.9	140–300
Overall maturity[a]	190	39.9	140–300
Marbling score[b]	450	57.0	290–520
USDA quality grade[c]	16.4	2.9	9.0–19.0
Adj. fat thick., mm	8.0	.3	7.0–20.3
Ribeye area, cm^2	74.2	1.4	58.1–93.5
KPH, %	1.5	.5	1.0–2.5
USDA yield grade	2.9	.6	1.9–4.1
Lean color[d]	5.6	1.8	2.0–8.0
Lean firmness[e]	5.9	2.2	1.0–8.0
Lean texture[f]	3.9	2.4	1.0–8.0
Heat ring[g]	4.5	1.1	1.0–5.0

[a]100 = A^{00}, 200 = B^{00}, 300 = C^{00}.
[b]300 = $traces^{00}$, 400 = $slight^{00}$, 500 = $small^{00}$.
[c]9 = utility, 16 = select, 19 = choice.
[d]1 = extremely dark red, 8 = bright cherry red.
[e]1 = extremely soft, 8 = very firm.
[f]1 = very coarse, 8 = very fine.
[g]1 = extreme heat ring, 5 = no heat ring.

by shear force values, after injection of $CaCl_2$ only 43% (LL) and 24% (SM) were still considered tough. Shear force and sensory tenderness may not always rank muscles the same for tenderness (Bouton et al., 1973). Those authors found that longissimus lumborum and longissimus thoracis were more tender than round muscles by sensory tenderness ratings but were less tender than round muscles according to WBS force. Those data agree with our results (Table 2). It has also been reported that longissimus steaks were less tender than round muscle steaks measured by sensory tenderness rating (McKeith et al., 1985).

Tenderness and juiciness scores for the LL were increased ($P < .05$) by the injection of $CaCl_2$, but no differences were observed in flavor intensity, or off-flavor scores. Although tenderness for SM was improved by the injection of $CaCl_2$, no effect was observed on juiciness, flavor intensity, or off-flavor ratings compared with the control. Improvements in sensory tenderness scores of the LL and SM were expected based on previous sensory evaluation results (Wheeler et al., 1993). However, in contrast to the previous studies using higher $CaCl_2$ concentrations, no off-flavors were detected and no increase was seen in flavor intensity in the present study. These contrasting results are most likely due to the lower concentration (200 vs 300 m*M*) and injection level used in the present study. Consumer evaluations

Table 2. Least squares means for sensory traits of longissimus lumborum and semimembranosus with and without calcium chloride injection at 7 days postmortem

Muscle and treatment	Weight added by injection, %[c]	Warner-Bratzler shear, kg	Tenderness[d]	Juiciness[d]	Flavor intensity[d]	Off-flavor[e]	Ease of fragmentation[d]	Amount of connective tissue[d]
Longissimus								
Control	5.2[a]	6.4[a]	4.8[b]	5.0[b]	4.8[a]	2.8[a]	4.8[b]	4.7[b]
SD	.34	.30	.08	.06	.07	.05	.08	.08
$CaCl_2$	5.1[a]	4.8[b]	5.4[a]	5.3[a]	4.7[a]	2.8[a]	5.4[a]	5.3[a]
SD	.38	.15	.04	.05	.07	.05	.06	.05
Semimembranosus								
Control	5.3[a]	5.5[a]	3.9[b]	4.8[a]	4.5[a]	2.7[a]	3.9[b]	3.6[b]
SEM	.43	.30	.08	.06	.06	.05	.08	.08
$CaCl_2$	5.4[a]	4.5[b]	4.1[a]	4.8[a]	4.5[a]	2.6[a]	4.2[a]	3.9[a]
SD	.47	.15	.13	.11	.11	.12	.13	.12

[a,b]Means in a column within muscle with different superscripts differ ($P < .05$).
[c]Calculated by (weight before injection − weight after injection/weight before injection) × 100.
[d]8 = extremely, 7 = very, 6 = moderately, 5 = slightly tender, juicy, intense, easy, and none. 4 = slightly, 3 = moderately, 2 = very, 1 = extremely tough, dry, bland, hard, and abundant.
[e]4 = none and 1 = intense.

Table 3. Least squares means for lean color scores and percentage of discoloration of longissimus lumborum and semimembranosus with and without calcium chloride injection during a 5-day retail display

Muscle and treatment	Control, d					$CaCl_2$, d					CV
	1	2	3	4	5	1	2	3	4	5	
Longissimus											
Color[a]	6.0[c]	5.9[c]	6.0[c]	5.9[c]	5.9[c]	5.9[c]	5.8[c]	5.9[c]	5.7[c]	5.8[c]	7.46
Discoloration[b]	1.1[d]	1.0[d]	1.2[d]	1.6[d]	1.9[d]	1.3[d]	1.2[d]	1.2[d]	2.2[c]	2.9[c]	49.03
Semimembranosus											
Color[a]	6.0[c]	6.0[c]	6.1[c]	6.0[c]	6.1[c]	5.7[d]	5.5[d]	5.7[d]	5.7[d]	5.7[d]	7.46
Discoloration[b]	1.4[d]	1.2[d]	1.4[d]	1.8[d]	1.8[d]	1.1[d]	1.1[d]	1.2[d]	1.9[d]	2.2[c]	49.03

[a]8 = very dark red, 7 = dark red, 6 = moderately dark red, 5 = slightly dark red, 4 = bright cherry red, 1 = very bleached red.
[b]7 = 100%, 4 = 20 to 59%, 3 = 11 to 19%, 2 = 1 to 10%, 1 = 0%.
[c,d]Means in a row with the same superscript are not different ($P > .05$).

under retail store conditions on LL and SM samples from this study show no flavor problems exist in beef injected with $CaCl_2$ (Wheeler and Miller, 1993). Ease of fragmentation was rated higher ($P < .05$) by sensory panelists for both LL and SM injected with $CaCl_2$. Less sensory detectable connective tissue was found in steaks injected with $CaCl_2$ than in control steaks, consistent with Morgan et al. (1991).

Visual color scores for LL were not affected ($P > .05$) by the injection of $CaCl_2$ during a 5-d display (Table 3). However, SM steaks injected with $CaCl_2$ had improved ($P < .05$) lean color ratings during 5 d of display compared with the control steaks. Percentage of discoloration was not different ($P > .05$) from controls through d 3 of display for injected LL, but injected LL was more ($P < .05$) discolored at d 4 and 5. The SM injected with $CaCl_2$ did not differ ($P > .05$) in lean discoloration scores compared with controls through d 4, but were more ($P < .05$) discolored at d 5 of display. Wheeler et al. (1993) also reported no changes in lean color through d 3 of display for LL and SM; however, no previous data has been reported for display through 5 d on $CaCl_2$-treated steaks

Minolta colorimeter L*, a*, and b* readings for LL were not affected ($P > .05$) by $CaCl_2$ treatment through d 3, but L* values were higher (a lighter red color, $P < .05$) for injected meat on d 4 of display (Table 4). The L* and b* (more yellow color) colorimeter readings of $CaCl_2$-injected SM were higher ($P < .05$) than for control steaks ($P < .05$) for each day of display except for d 3 L* values that were lower in injected steaks. The a* (more red color) values of SM were higher ($P < .05$) for $CaCl_2$ injected than control steaks on d 1 of display. Because most meat products reach the consumer within 3 d of display, these minimal changes observed in meat color would have little effect on consumer purchase decisions related to lean color.

The percentage of drip loss from the SM steaks injected with $CaCl_2$ was higher ($P < .05$) than that of the control steaks (Table 5). The injection of $CaCl_2$ did not affect ($P > .05$) cooking traits (internal temperature, cooking loss in percentage, cooking time in minutes, cooking rate in grams/minutes, or cooked color score) of steaks from either LL or SM. The LL and SM injected with $CaCl_2$ had a higher ($P < .05$) purge loss percentage during the 7-d postmortem storage (Figure 1). Based on these findings, the segment of the industry applying the injection process

Table 4. Least squares means for L*, a*, and b* values of longissimus lumborum and semimembranosus with and without calcium chloride injection during a 4-day retail display

Muscle and treatment	d 1			d 2			d 3			d 4		
	L*[a]	a*[b]	b*[c]	L*	a*	b*	L*	a*	b*	L*	a*	b*
Longissimus												
Control	42.1[d]	13.5[d]	6.6[d]	41.0[d]	11.6[d]	7.0[d]	41.8[d]	12.0[d]	6.7[d]	42.3[d]	11.9[d]	6.4[d]
$CaCl_2$	42.9[d]	13.3[d]	6.7[d]	41.9[d]	12.1[d]	6.6[d]	42.5[d]	11.3[d]	6.9[d]	44.0[e]	11.1[d]	6.9[d]
Semimembranosus												
Control	40.1[e]	13.0[e]	6.9[e]	40.7[e]	12.0[d]	7.2[e]	40.9[d]	11.2[d]	6.9[e]	41.4[e]	11.2[d]	7.0[e]
$CaCl_2$	42.5[d]	14.5[d]	7.6[d]	42.4[d]	12.6[d]	7.9[d]	42.2[d]	11.8[d]	8.2[d]	43.2[d]	11.7[d]	7.9[d]
CV	5.59	12.78	15.98	2.50	16.61	12.16	5.00	33.2	24.13	8.53	11.74	17.68

[a]L* = lightness; 100 = white, 0 = black.
[b]a* = redness; green = −80, red = 100.
[c]b* = yellowness; blue = −50, yellow = 70.
[d,e]Means in a column within muscle with different superscripts differ ($P < .05$).

Table 5. Least squares means for cooking data of longissimus lumborum and semimembranosus with and without calcium chloride injection

Muscle and treatment	Drip loss, %	Internal meat temperature, °C[c]	Cooking loss, %	Cooking time, min	Cooking rate, g/min	Cooked color score
Longissimus						
Control	2.8[a]	70.0[a]	29.6[a]	27.8[a]	7.4[a]	4.7[a]
$CaCl_2$	2.2[a]	70.7[a]	30.8[a]	28.5[a]	8.2[a]	5.1[a]
Semimembranosus						
Control	2.2[b]	70.0[a]	33.3[a]	35.3[a]	8.0[a]	4.3[a]
$CaCl_2$	3.3[a]	69.7[a]	31.5[a]	33.6[a]	7.9[a]	4.3[a]
CV	58.32	21.0	14.38	1.63	24.38	16.83

[a,b]Means in a column within a muscle with the same superscript are not different ($P > .05$).
[c]End point internal temperature average of the sensory steaks.

will benefit the most from this process because of extra weight added to the product during the injection. Retailers or food service will observe losses due to the increase in purge during aging as a result of the $CaCl_2$ injection, but customers will be provided with more consistently tender beef product.

The improvement in tenderness observed in meat injected with $CaCl_2$ from the most vaiable and problematic *Bos indicus* cattle types should have an immediate impact on the beef industry. The packer will be able to assure the retailer and the consumer of a more uniformly tender beef product regardless of the quality grade it possesses. Beef that is not presently selected for top choice programs (i.e., modest or greater marbling) could be injected with $CaCl_2$ by the packer and sold on the injected weight basis, ensuring a more consistently tender product.

Implications

The effects of $CaCl_2$ injection, applied under commercial conditions, were consistent with results from laboratory experiments using 200 m*M* $CaCl_2$ injection at 5% (wt/wt). Warner Bratzler Shear force values and trained sensory panel ratings indicated that the percentage of tough meat was reduced in both muscles. Commercial application of $CaCl_2$ injection improved meat palatability with minimal effect on other meat quality traits. Adaptation of this tenderizing procedure by the meat industry would reduce the variation found in beef tenderness.

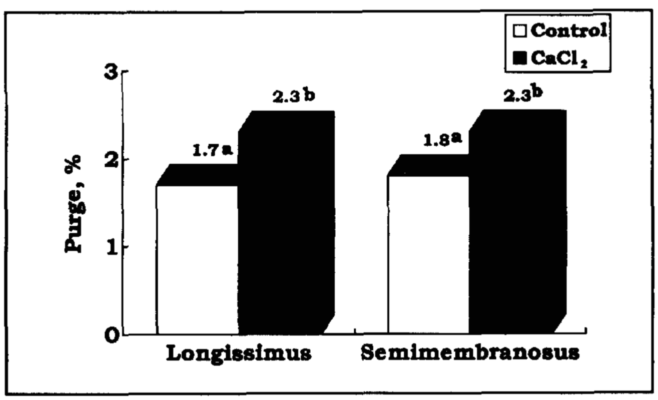

Figure 1. Least squares means for percentage purge loss of longissimus and semimembranosus muscles after 7 d postmortem. [a,b]Means with different superscripts differ ($P < .05$), SEM = .53%.

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