EFFECTS OF CALCIUM CHLORIDE INJECTION AND HOT BONING ON THE TENDERNESS OF ROUND MUSCLES

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ABSTRACT

Two experiments were conducted to determine the effect of $CaCl_2$ injection on round muscles obtained from *Bos indicus* bulls and late-castrate steers. In Exp. 1, the biceps femoris (BF) muscle from the left side of each of 15 bull carcasses was injected within 30 min postexsanguination with .3 *M* $CaCl_2$ at 10% by weight while either intact (n = 8) on the carcass or after hot boning (n = 7). The right sides served as controls. In Exp. 2, the semimembranosus (SM) muscles from the carcasses of nine steers (castrated at 16 mo of age) were hot-boned within 30 min postexsanguination and one-half were injected with $CaCl_2$ as described above. Hot boning had no effect ($P > .05$) on shear force values. Calcium chloride injection dramatically reduced shear force requirements at 1, 8, and 14 d postmortem compared with noninjected controls in both experiments. Cooking traits of the SM muscle were not affected ($P > .05$) by $CaCl_2$ injection. However, BF muscles injected with $CaCl_2$ required more ($P < .05$) time to cook and had greater ($P < .05$) cooking losses than BF controls. Calcium chloride injection of prerigor round muscles reduced aging time needed for normal tenderization to 1 d postmortem. Hot boning was successfully used in conjunction with $CaCl_2$ injection to facilitate the injection process.

Key Words: Beef, Calcium Chloride, Hot Boning, Tenderness

J. Anim. Sci. 1991. 69:4871–4875

Introduction

Numerous researchers have reported that meat from cattle with *Bos indicus* breeding was less tender than meat from cattle with *Bos taurus* inheritance (Ramsey et al., 1963; Koch et al., 1982; Peacock et al., 1982; Crouse et al., 1987, 1989; Johnson et al., 1990; Wheeler et al., 1990; Whipple et al., 1990). In addition, Morgan et al. (1991) concluded from the national beef tenderness survey that round and chuck cuts in particular needed improvement in tenderness.

It has been demonstrated that meat tenderness can be improved dramatically at 1 d postmortem by infusing whole carcasses (Koohmaraie et al., 1988, 1989; Koohmaraie and Shackelford, 1991) or by injecting a portion of a carcass (Koohmaraie et al., 1990) with a $CaCl_2$ solution within 1 h postmortem. The mode of action of $CaCl_2$ is believed to be acceleration of postmortem proteolysis via the calpain proteolytic system. This process consistently produces uniformly tender meat at 1 d postmortem based on the means and SD of shear force of individual muscle cores. Koohmaraie et al. (1990) reported that the additional calcium did not cause toughening as a result of Ca^{2+}-induced contraction in muscles left attached to the carcass until after rigor mortis was completed. However, this might not be true with muscle hot-boned and injected with $CaCl_2$ soon after slaughter. Thus, the objective of this research was to determine the effect of

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Received March 25, 1991.
Accepted June 29, 1991.

$CaCl_2$ injection and hot boning on the tenderness of round muscles from *Bos indicus* crossbred bulls and late-castrate steers.

Materials and Methods

Experiment 1 included 15 *Bos indicus* bulls (3/8, 1/2, or 5/8 Brahman or Sahiwal by Angus or Hereford) placed on feed weighing 250 kg at 7 mo of age. The bulls were fed a growing diet (76.0% corn silage, 20.0% corn, 2.0% soybean meal, 2.0% concentrate; CP 11.7%, ME 2.83 Mcal/kg) for approximately 11 mo and slaughtered at 18 mo of age weighing 551 kg. Experiment 2 included nine *Bos indicus* late-castrate steers (3/8, 1/2, or 5/8 Brahman or Sahiwal by Angus or Hereford) placed on feed weighing 262 kg at 7 mo of age. The late-castrate steers were castrated at 16 mo of age. The late-castrate steers were fed the same growing diet for 12 mo and slaughtered at 19 mo of age, weighing 547 kg.

Experiment 1 was conducted as a split-plot design. The biceps femoris (BF) muscles from both sides were used. The whole plot was hot-boning treatment. Eight carcasses were left intact and the BF muscle was hot-boned at 30 min postexsanguination from seven carcasses. The split-plot treatment was $CaCl_2$ injection. The BF muscles from the right sides served as controls. The BF muscles from the left sides were injected with .3 *M* $CaCl_2$ at 10% by weight with a hand stitch pump[3] at 30 min postexsanguination. Koohmaraie et al. (1988) found that infusing water had no effect on shear force; thus, the controls in the current study were not injected with water.

Experiment 2 was conducted as a completely randomized design. The semimembranosus (SM) muscle was hot-boned from both sides of each of the nine carcasses at 30 min postexsanguination. The SM muscles from the right sides served as controls and the SM muscles from the left sides were injected with $CaCl_2$ as described above.

All hot-boned muscles were placed in polyethylene bags. All hot-boned muscles and intact sides were chilled 24 h at 2°C. The BF muscles (Exp. 1) from the intact sides were removed from the sides at 24 h postmortem. Six 3-cm-thick steaks were cut from each muscle at 24 h postmortem. Two steaks per muscle were allocated for aging 1, 8, or 14 d postmortem at 2°C.

All steaks were cooked for shear force determination after the appropriate aging time; thus, the steaks were never frozen. Steaks were broiled on Farberware Open Hearth electric broilers[4] to an internal temperature of 70°C. Steaks were turned after reaching 40°C. Internal temperature was monitored with iron constantan thermocouple wires attached to a Honeywell potentiometer[5] and placed in the geometric center of the steaks. After cooking, steaks were chilled 24 h at 3°C, then six 1.27-cm-diameter cores were removed from each steak parallel to the muscle fiber orientation and sheared once with an Instron model 1132/Microcon II with a Warner-Bratzler shear attachment. The crosshead speed was 5 cm/min and the fail criterion was 75%.

Data from Exp. 1 were analyzed by ANOVA with the GLM procedure of SAS (1985) for a split-plot design. The whole plot was hot boning and the split plot was $CaCl_2$ treatment. Error terms specified in the model included replication × hot boning for the whole plot and the residual error for the split plot. Data for Exp. 2 were analyzed by ANOVA with GLM of SAS for a completely randomized design. Mean separation was performed with least squares procedures.

Results

Table 1 characterizes the carcasses used in these experiments. In Exp. 1, $CaCl_2$ injection of BF muscles from carcasses of Brahman crossbred bulls significantly reduced ($P < .05$) shear force requirements at all postmortem times (Table 2). Postmortem aging necessary to ensure tender meat was reduced to 1 d. Even after 14 d of postmortem aging, $CaCl_2$-injected meat was more ($P < .05$) tender than the control meat. Hot boning had no effect ($P > .05$) on shear force of BF muscles, possibly because of limited observations. The interaction of hot boning and $CaCl_2$ injection was significant ($P < .05$) for 8 d of postmortem aging. A greater reduction in shear force requirements with $CaCl_2$ injection occurred in hot-boned BF muscle aged 8 d than in intact BF muscle.

[3]Presto Precision Products, Inc., Farmingdale, NY.
[4]Farberware Company, Bronx, NY.
[5]Honeywell, Inc., Scarborough, ON, Canada.

TABLE 1. CARCASS TRAITS FOR EXPERIMENTS 1 AND 2

Traits	Exp. 1	Exp. 2
Hot carcass weight, kg	352 ± 46	345 ± 52
Adjusted fat thickness, cm	1.1 ± .4	1.4 ± 1.0
Longissimus muscle area, cm^2	84.5 ± 9.0	79.4 ± 9.7
Kidney, pelvic, and heart fat, %	2.6 ± .8	2.8 ± 1.1
USDA yield grade	2.8 ± .5	3.4 ± 1.0
Marbling[a]	373 ± 33	382 ± 35
USDA quality grade	$Select^+$	$Select^+$

[a]Traces = 200–299; Slight = 300–399; Small = 400–499.

In Exp. 2, all SM muscles from carcasses of late-castrate Brahman crossbred steers were hot-boned. As with the BF muscle, $CaCl_2$ injection resulted in significant reduction (P < .05) in shear force requirements at all postmortem aging times (Table 3). Even though the control SM muscles were initially tougher than the BF muscles, the $CaCl_2$ injection was equally successful at increasing tenderness by 1 d postmortem.

Cooking characteristics were not affected by time postmortem; thus, means shown were pooled across aging times. Cooking time, cooking rate, and cooking loss of hot-boned SM muscle were not affected (P > .05) by $CaCl_2$ injection (Table 3). However, percentage of cooking loss was higher (P < .05), cooking time longer (P < .05), and cooking rate slower (P < .05) in steaks from $CaCl_2$-injected BF muscles (Table 4). Although cooking loss was not affected (P > .05) by hot boning, cooking rate was faster (P < .05) in hot-boned BF steaks. The interaction of hot boning and $CaCl_2$ injection of BF muscles resulted in a greater increase (P < .05) in cooking loss with $CaCl_2$ injection of hot-boned muscle than in control muscle.

Discussion

It is well documented that meat from *Bos indicus* cattle is less tender than meat from *Bos taurus* cattle (Crouse et al., 1989). It also has been shown that muscles from the round are less tender than muscles from other carcass locations (McKeith et al., 1985a,b). In fact, Morgan et al. (1991) concluded from the national beef tenderness survey that round and chuck cuts in particular needed improvement in tenderness. Koohmaraie et al. (1988, 1989, 1990) have conclusively demonstrated that infusing carcasses or injecting portions of carcasses with .3 *M* $CaCl_2$ within 1 h postmortem ensures consistently tender meat from the longissimus muscle at 1 d postmortem. Consistent with this previous work on longissimus muscle, results from the current study indicate that $CaCl_2$ injection also was effective on tougher BF and SM muscles from *Bos indicus* bulls and late-castrate steers. All research to date in this area indicates that 1 d postmortem shear force requirements are consistently reduced to 3 or 4 kg by increasing the Ca^{2+} concentration of the muscle immediately postmortem. We believe that the increased tenderization results from activation of μ-calpain (CDP-I) and m-calpain (CDP-II) by exogenous calcium.

In agreement with our findings, Koohmaraie et al. (1990) reported that injection of beef loins with $CaCl_2$ within 1 h postmortem resulted in increased cooking losses. However, in contrast to our results, they found no effect on cooking rate. They also reported that infusion of lamb carcasses with $CaCl_2$ soon

TABLE 2. WARNER-BRATZLER SHEAR FORCE (kg) FOR BICEPS FEMORIS MUSCLES AS AFFECTED BY $CaCl_2$ INJECTION, HOT BONING, AND TIME POSTMORTEM (EXP. 1)

	Hot-boned (HB)		Intact		Probability		
Days postmortem	$CaCl_2$	Control	$CaCl_2$	Control	HB	$CaCl_2$	Interaction
1	3.74 ± .26	6.38 ± .27	3.62 ± .26	5.62 ± .27	.11	.01	.24
8	3.35 ± .27	5.48 ± .28	3.82 ± .27	4.62 ± .28	.49	.01	.02
14	3.68 ± .23	4.89 ± .25	3.28 ± .24	4.60 ± .25	.16	.01	.83

TABLE 3. WARNER-BRATZLER SHEAR FORCE AND COOKING TRAITS OF HOT-BONED SEMIMEMBRANOSUS MUSCLES AS AFFECTED BY $CaCl_2$ INJECTION AND TIME POSTMORTEM (EXP. 2)

	Shear force, kg					
Treatment	1 d	8 d	14 d	Cooking time, min[a]	Cooking rate, g/min[a]	Cooking loss, %[a]
Control	8.95 ± .7	8.51 ± .7	7.30 ± .7	35.5 ± 1.6	10.0 ± .5	29.4 ± 1.0
$CaCl_2$	3.67 ± .7	3.20 ± .7	3.21 ± .7	39.0 ± 1.6	9.1 ± .5	32.0 ± 1.0
Probability	.01	.01	.01	.14	.20	.06

[a]Data include all postmortem times.

after slaughter had no effect on any cooking characteristics. An increase of 3 to 5% in cooking losses may have resulted because the meat retained some of the injected solution but would not necessarily result in a product with decreased juiciness compared to the control. Trained sensory panel evaluation of meat infused or injected with $CaCl_2$ has not been conducted. However, results from a trained flavor profile panel indicate that infusion of lamb carcasses with .3 *M* $CaCl_2$ had no effect on desirable flavor attributes and only slightly increased salty and bitter flavor descriptors (St. Angelo et al., 1991). Furthermore, they reported that the addition of antioxidants to the infusion solution inhibited warmed-over flavor development and resulted in more desirable flavor than either control or $CaCl_2$ infusion treatments alone.

Hot boning of beef has traditionally been considered as a means of decreasing energy and labor costs associated with chilling and fabricating beef carcasses. However, its use has not been accepted by the beef industry. In a review of hot boning, Seideman and Cross (1982) concluded that cooking traits were generally unaffected by hot-boning treatments. However, they reported that tenderness of hot-boned meat was sometimes decreased. This decrease varied greatly, though, depending on the conditions of the hot-boning process. In agreement with our data, Schmidt and Keman (1974) found no differences in any palatability trait of longissimus muscle, BF or SM muscle hot-boned at 1 h postmortem compared with conventionally processed cuts. Because our data indicate that hot boning had no detrimental effect on tenderness or cooking traits, hot boning could be used on round cuts to facilitate injection of $CaCl_2$, thereby increasing the tenderness of these cuts. Even if hot boning were detrimental to tenderness, the success of $CaCl_2$ injection in improving tenderness of hot-boned meat should enhance the potential use of hot boning in the beef industry.

Additional research to determine the appropriate $CaCl_2$ concentration and level of injection is needed before successful industry adoption of this process can be accomplished. Much easier industry adoption of the process could occur if the injection could be performed after 24 h postmortem. Then hot boning would be unnecessary and the injection could be performed at processing facilities (in place of blade tenderization) at any time postmortem, rather than at slaughter facilities soon after slaughter. This possibility is currently being investigated.

Implications

Results from this study indicate that the tenderness of round muscles from carcasses of *Bos indicus* bulls and late-castrate steers can

TABLE 4. COOKING TRAITS OF BICEPS FEMORIS MUSCLES AS AFFECTED BY $CaCl_2$ INJECTION AND HOT BONING (EXP. 1)

	Hot-boned (HB)		Intact		Probability		
Cooking traits[a]	$CaCl_2$	Control	$CaCl_2$	Control	HB	$CaCl_2$	Interaction
Cooking time, min	41.1 ± 1.6	35.6 ± 1.7	44.1 ± 1.6	34.2 ± 1.7	.61	.01	.17
Cooking rate, g/min	8.1 ± .3	9.7 ± .3	6.9 ± .3	8.8 ± .3	.01	.01	.63
Cooking loss, %	30.0 ± .8	27.1 ± .9	31.4 ± .8	24.8 ± .9	.61	.01	.04

[a]Data include all postmortem times.

be improved by injecting them with calcium chloride soon after slaughter. Tenderness was increased in hot-boned and conventionally chilled meat such that aging longer than 1 d postmortem was not necessary to ensure uniformly tender meat. Hot boning was successfully used in conjunction with calcium chloride injection to facilitate the injection process.

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