EFFECTS OF ELECTRICAL STIMULATION AND HOT BONING UPON PHYSICAL CHANGES, COOKING TIME AND LOSSES, AND TENDERNESS OF BEEF ROASTS

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INTRODUCTION

THE MEAT industry in the United States (Henrickson, 1975) is one of the six largest users of energy; consequently, alternatives toward conserving energy are being investigated. Removal of muscle and muscle systems prior to chilling the bovine carcass has been investigated (Schmidt and Gilbert, 1970; Kastner et al., 1976; Kastner and Russell, 1975; Kenrickson, 1975) to determine the feasibility of hot boning as an alternative to conventional fabrication. Hot boning of the carcass prior to chilling saves energy by: 1) chilling only the edible portion of the carcass; 2) reducing the requirements for refrigeration facilities; 3) reducing transportation cost; 4) more rapid turnover of inventory; and 5) reducing needed labor. The problem with hot boning is one of tenderness (Weiner et al., 1966; Kastner and Russell, 1975; Ray et al., 1979; Griffin et al., 1979). In addition, the use of hot boned muscles to produce a pre-cooked product has shown some distortion of shape, higher cooking yields and significant energy savings (Cia and Marsh, 1976; Marsh, 1977, Ray et al., 1979; Griffin et al., 1979). Interest in electrical stimulation (Chrystall and Haggard, 1976; Davey et al., 1976). Savell et al., 1978; Ray et al., 1978; Stiffler et al., 1978; Cross, 1979), as a means of improving tenderness, has received considerable attention. The adaptation of new techniques (electrical stimulation and hot boning) into a system approach into the meat industry must consider, not only the improvement in efficiency, but also their influence upon product quality.

This study was conducted to investigate the concomitant effects of electrical stimulation and hot boning upon physical changes, length of cooking time and losses, and tenderness of roasts (semitendinosus and semimembranosus muscles) of carcasses from steers and Mor-Lean (short scrotum) cattle.

MATERIALS AND METHODS

FORTY Mor-Lean carcasses and forty-eight steer carcasses of crossbred breeding were utilized in this study. Cattle were fed a high energy finishing ration (70-80% concentrate) for 147 days. One-half of the left and right sides were electrically stimulated (ES) [100 impulses, 1 second duration, 110 volts, < 5 amps] within 45 minutes post-slaughter, while the remaining side served as a control (C). Semitendinosus (ST) and semimembranosus (SM) muscles were exised from the left side of all carcasses, within one hour postmortem (hot boned, HB), while the paired right side was processed 7 days (cold boned, CB) postmortem (2°C). The excised semitendinosus muscle was used intact; the semimembranosus muscle was divided longitudinally so that portions were of similar weight to that of the semitendinosus muscle. Excised muscles were immediately weighed, temperature monitored and measured for length, width (at 25.0, 50.0 and 75.0% of the length) and depth at the deepest point of the muscle. Similar measurements were recorded subsequent to cooking.

Cooking preparation involved rubbing each muscle with a commerical roast beef spice preparation (B. Heller and Co.®), placed in L600 Cryovac® bag, vacuumized (Multivac®) and cooked to an internal temperature of 63°C in a steam oven. Internal roast temperature was monitored during cooking with temperature probes (Omega®) and a Digilloger®. The cooking schedule was: 1st hour at 68°C; 2nd hour at 74°C; and the remaining time at 80°C. Cooking time was recorded, percent cooking yield recorded and the product was chilled to 38-40°C. Subsequently, a 3.8 cm thick sample was removed for Warner-Bratzler shear (WBS) determination. Three cores (1.27 cm) from each sample were sheared and all cores were sheared twice. Adjacent to the WBS sample, a 10 cm sample of each roast was removed from the center portion, placed in a bag with juices, vacuumized and frozen (-29°C). Following about 45 days of storage, the samples were evaluated at the USDA Meat Science Research Lab, Beltsville, Maryland, by an eight-member trained panel.

Data were analyzed with a paired-t distribution analysis (Steel and Torrie, 1960) to determine significance of difference between hot and cold boned and between electrically stimulated and control sides of beef.

RESULTS

Table 1. Carcass traits and measurements of beef carcasses.

Trait	Steers (N=24)	Mor-Lean (N=20)
USDA Quality grade[c]	10	9
USDA Yield grade	3.4 ±.9[a]	2.8±.7[b]
Adjusted fat thickness (cm)	1.22±.51[a]	.91±.30[b]
Rib eye area (cm^2)	66.71±10.3[a]	71.10±9.7[b]
Kidney, heart and pelvic fat (%)	2.7 ±.56[a]	2.3 ±.42[b]
Carcass weight (kg)	297 ±23	294 ±30

[a,b]Means with different superscripts differ significantly (P < 0.01)

[c]Scores based on 11 = USDA High Good; 10 = USDA Average Good; 9 = USDA Low Good

MEAN carcass traits and measurements for the steer and Mor-Lean cattle are presented in Table 1. Quality grades of the carcasses from the two sex groups were similar, but the Mor-Lean carcasses exhibited less fat thickness, less kidney, heart and pelvic fat and larger rib eye areas than steer carcasses. The mean hot carcass weights were 297 and 294 kg for steer and Mor-Lean, respectively.

Changes in the physical characteristics of the St and SM muscle roasts, as influenced by sex, electrical stimulation and method of boning are presented in Tables 2 and 3, respectively. Roasts from the ST of steer and Mor-Lean carcasses responded similarly to cooking within each method of postmortem boning; however, HB roasts became significantly shorter (-29% vs -19.4%; ($P < 0.05$), wider (+3.7 vs -3.1%;($P < 0.05$), and deeper (+15.8% vs -1.19 ($P < 0.01$) than roasts removed 7 days postmortem (CB). Hot-boned roasts from the SM of steer carcasses, demonstrated less ($P < 0.01$) shortening (+34.9% vs +44.1%) than HB roasts from Mor-Lean carcasses. Furthermore, roasts (SM) from CB, C steer carcasses showed less ($P < 0.01$) shortening (16% vs 23%) than CB, ES roasts. Cia and Marsh (1976), using bovine sternomandibularis samples, reported a 50.4% reduction in length when samples were microwaved 0.7 to 3.1 hr postmortem, which is similar to the shortening observed for the HB SM roasts (-44.1%) in this study.

Table 2. Physical characteristics of semitendinosus muscle roast as influenced by sex, electrical stimulation, and method of postmortem boning.

ITEM	Steer		Mor-Lean	
	Electrically stimulated	Control	Electrically stimulated	Control
	Hot-boned			
Change in (fresh vs cooked):				
Length, %	-26.9[a]	-30.1[a]	-29.3[a]	-29.5[a]
Width, %	+3.9	+2.3	+6.2[a]	+2.2
Depth, %	+18.2[a]	+12.0[a]	+14.6[a]	+18.2[a]
No. of roasts	12	12	10	10
	Cold-boned			
Change in (fresh vs cooked):				
Length, %	-17.6[b]	-20.4[b]	-20.4[b]	-19.0[b]
Width, %	-2.7	-3.7	-4.3[b]	-1.8
Depth, %	+2.7[b]	-1.4[b]	0[b]	-2.4[b]
No. of roasts	12	12	10	10

[a,b]Means in the same column, within postmortem treatment (ES or C), with different superscripts differ significantly ($P < 0.01$).

There appeared to be a consistent trend for HB ST roasts to slightly increase in width (+3.2%); while HB SM changes were less (+0.8%) and more erratic. The CB ST and SM roasts showed a slight reduction in width (-3.7). These changes in width are similar (+3.2 vs +2.9) for HB ST but the changes observed in the HB SM (+0.8% vs -8.8%) are much less than those reported by Ray <u>et al</u>. (1979), which is undoubtedly a reflection of the lower (63°C vs 68°C) cooking temperature. Furthermore, the distortion in shape that normally accompanies the cooking of hot boned muscles can be partially negated by method of preparation and serving.

Table 3. Physical characteristics of semimembranosus muscle roast as influenced by sex, electrical stimulation, and method of postmortem boning.

ITEM	Steer		Mor-Lean	
	Electrically stimulated	Control	Electrically stimulated	Control
	Hot-boned			
Change in (fresh vs cooked):				
Length, %	-36.9[a,c]	-33.0[a,c]	-45.1[a,d]	-43.1[a,d]
Width, %	+4.3	-4.3	+4.9[a]	-1.6
Depth, %	+27.7[a,c]	+24.4[a,c]	+37.5[a,d]	+33.3[a,d]
No. of roasts	12	12	10	10
	Cold-boned			
Change in (fresh vs cooked):				
Length, %	-23.0[b,c]	-16.0[b,d]	-22.1[b,c]	-21.8[b,c]
Width, %	-1.8	-2.8	-10.9[b]	+3.6
Depth, %	0[b,c]	-19.7[b,d]	+6.8[b,c]	-3.8[b,c]
No. of roasts	12	12	10	10

[a,b]Means in the same column, within postmortem treatment (ES or C), with different superscripts differ significantly ($P < 0.01$).

[c,d]Means in the same row, within method of boning, with different superscripts are different ($P < 0.01$).

Roast depth of the HB ST, as measured through the thickest section, was not influenced by sex or electrical stimulation; whereas, roasts (HB SM) from steer carcasses exhibited less depth changes (+26.1% vs +35.4%) than those from Mor-Lean carcasses. It is apparent from these data that the observed decrease in the length of HB roasts was accompanied by a similar increase in depth and that the length and depth changes were less pronounced in the HB SM from steer carcasses. Roasts from CB ST and SM showed less change in depth than HB roasts.

Table 4 presents the mean value of physical traits investigated grouped by sex and muscle classifications. Change in length of roasts was -34.1% and -19.9% for HB and CB, respectively, which coincides with a +24.6% and -1.9% change in depth of HB and CB, respectively. Width changes were minimal.

Table 4. Mean values for physical characteristics of beef roasts (SM and ST) as influenced by method of boning and electrical stimulation.

ITEM	Method of boning			
	Hot-boned		Cold-boned	
	Electrically stimulated	Control	Electrically stimulated	Control
Fresh muscle:				
Length, cm	$34.7 \pm .8^{a}$	$34.8 \pm .8^{a}$	$34.4 \pm .5^{a}$	$33.7 \pm .5^{a}$
Width, cm	12.5 ± 1.2	13.0 ± 1.2	11.3 ± 1.1	11.2 ± 1.0
Depth, cm	7.5 ± 1.1^{a}	8.4 ± 1.2^{a}	7.7 ± 1.1	8.3 ± 1.1
Cooked product:				
Length, cm	$25.8 \pm .54^{b,c}$	$26.0 \pm .56^{b,c}$	$28.5 \pm .5^{b,d}$	$28.3 \pm .5^{b,d}$
Width, cm	13.1 ± 1.2	13.0 ± 1.2	11.3 ± 1.1	11.0 ± 1.1
Depth, cm	$9.1 \pm 1.1^{b,c}$	$10.3 \pm 1.5^{b,c}$	$7.9 \pm .8^{d}$	$7.8 \pm .8^{d}$
Change in (fresh vs cooked):				
Length, cm	-34.5	-33.8	-20.7	-19.1
Width, cm	+4.8	0	0	-1.8
Depth, cm	+26.7	+22.6	+2.5	-6.4
No. of roasts	44	44	44	44

[a,b]Means in the same column, within postmortem treatment (ES or C) with different superscripts differ significantly ($P < 0.01$).

[c,d]Means in the same row, within postmortem treatment (ES or C) with different superscripts differ significantly ($P < 0.05$).

The decreased tenderness ($P < 0.01$) of cooked prerigor ST and SM roasts (Table 5 and 6) when compared with CB roasts confirms the findings of Weiner et al. (1966), Montgomery et al. (1977) and Ray et al. (1979). Electrical stimulation or sex classification did not significantly influence the WBS shear reading of the HB or CB roasts, but there was a tendency for roasts from steer carcasses to have lower WBS and slightly higher taste panel tenderness. Griffin et al. (1979) reported no difference in WBS or taste panel tenderness of CB or HB biceps femoris muscle of ES and C carcasses, while numerous workers have reported ES to increase tenderness of CB product (Crystall et al., 1976; Davey et al., 1976; Savel et al., 1978; Ray et al, 1978; Stiffler et al., 1978).

Table 5. Influence of electrical stimulation and method of postmortem boning upon tenderness, cooking yield and time of cooking (63°C, internally) for semitendinosus beef roasts.

ITEM	Method of boning			
	Hot-boned		Cold-boned	
	Steer	Mor-lean	Steer	Mor-lean
Warner-Bratzler shear, kg/1.27 cm				
Electrically stimulated	$4.98 \pm .57^{a}$	$5.14 \pm .58^{a}$	$2.90 \pm .23^{b}$	$3.35 \pm .24^{b}$
Control	$5.05 \pm .89^{a}$	$5.42 \pm .94^{a}$	$2.92 \pm .24^{b}$	$3.20 \pm .25^{b}$
Cooking yield, %				
Electrically stimulated	$92.4 \pm .69^{a,c}$	$90.9 \pm .68^{a,d}$	83.7 ± 1.65^{b}	82.0 ± 1.60^{b}
Control	$92.7 \pm .72^{a,c}$	$90.4 \pm .77^{a,d}$	83.7 ± 1.65^{b}	84.8 ± 1.75^{b}
Time to cook, min/kg				
Electrically stimulated	74.9 ± 5.69^{a}	71.9 ± 5.60^{a}	88.1 ± 6.04^{b}	85.6 ± 6.35^{b}
Control	62.7 ± 6.00^{a}	65.8 ± 6.37^{a}	102.9 ± 7.20^{b}	85.5 ± 6.40^{b}

[a,b]Means in the same row, within sex, with different superscripts differ ($P < 0.01$)

[c,d]Means in the same row, between sex, with different superscripts differ ($P < 0.01$)

Cooking yield was determined as the difference in weight between the raw muscle plus seasonings and cooked weight of the roast. Cooking yield was influenced ($P < 0.01$) by method of boning and sex classification for the HB ST roast; whereas, electrical stimulation exerted little or no response. Roasts from HB ST of steer carcasses had 2% higher cooking yield than roasts from Mor-Lean carcasses. Furthermore, HB ST and SM roast had 8.3% and 8.7% respectively, higher cooking yields than their CB counterparts.

Table 6. Influence of electrical stimulation, method of postmortem boning, and sex upon tenderness, cooking yield and time of cooking (63°C, internally) for semimembranosus beef roasts.

ITEM	Method of boning			
	Hot-boned		Cold-boned	
	Steer	Mor-lean	Steer	Mor-lean
Warner-Bratzler shear, kg/1.27 cm				
Electrically stimulated	6.18$\pm$.68[a]	6.50$\pm$.69[a]	2.95$\pm$.35[b]	3.92$\pm$.34[b]
Control	5.41$\pm$.72[a]	6.45$\pm$.77[a]	2.96$\pm$.35[b]	3.33$\pm$.37[b]
Tenderness panel scores[c]				
Electrically stimulated	4.8 $\pm$.20[a]	4.4 $\pm$.41[a]	6.4 $\pm$.21[b]	6.4 $\pm$.33[b]
Control	4.9 $\pm$.45[a]	4.7 $\pm$.27[a]	6.9 $\pm$.16[b]	6.2 $\pm$.21[b]
Cooking yield, %				
Electrically stimulated	89.5 $\pm$.67[a]	90.0 $\pm$.68[a]	83.5 $\pm$.72[b]	80.0 $\pm$.69[b]
Control	90.3 $\pm$.71[a]	88.8 $\pm$.75[a]	80.2 $\pm$.69[b]	79.9 $\pm$.77[b]
Time to cook, min/kg				
Electrically stimulated	80.6 $\pm$5.72[a]	77.5 $\pm$5.71[a]	90.3 $\pm$6.56[b]	100.0 $\pm$6.58[b]
Control	72.5 $\pm$6.03[a]	70.4 $\pm$6.39[a]	114.4 $\pm$6.79[b]	97.2 $\pm$6.97[b]

[a,b] Means in the same row within sex, with different superscripts, differ significantly ($P < 0.01$).

[c] 8 = extremely tender, 1 = extremely tough

Time required per unit weight (Tables 5 and 6) to cook HB roast from the ST and SM was less ($P < 0.01$) than for CB roast (-23.5 min/kg). When HB roasts were compared with CB roasts within ES as to time required per unit weight to cook, the ES roast required 18% (ST) and 20% less time per unit of weight; whereas the C roast that were HB required 47% (ST) and 47% (SM) less time than CB roasts cooked to the same internal temperature (63°C). Thus, HB ES roasts required 29% and 27% ($P < 0.01$) less cooking time than CB C roasts of the ST and SM, respectively. Ray et al. (1979) using HB roasts from ES Mor-Lean carcasses, which were cooked to an internal temperature of 67 C, found HB roasts required 28% and 29% less cooking time than CB roasts of ST and SM, respectively.

CONCLUSIONS

PRECOOKING HB beef, regardless of whether the carcasses were ES or not does not appear feasible because of increased toughness, which may be a result of heat stimulated contractions of heat rigor during cooking. Significant energy savings, using length of time of cooking, are apparent as are higher cooking yields for precooking hot-boned beef. Slicing roasts very thin, to overcome the reductions in tenderness, could render this product more acceptable to the consumer.

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