STORAGE STABILITY AND TENDERNESS OF TOP ROUND ROASTS COOKED PRE- OR POST-RIGOR FOLLOWING ELECTRICAL STIMULATION

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INTRODUCTION

PRE-RIGOR excision of beef roasts followed by immediate cooking of these warm roasts appears to offer many advantages, particularly in terms of energy required, over the conventional process of chilling the carcass prior to roast removal and subsequent cooking. Ray and Stiffler (1979) found that pre-rigor cooking of beef resulted in reduced cooking time and higher cooking yields when compared to the cooking of post-rigor, chilled roasts. However, that study suggested that the pre-rigor cooked roasts underwent muscle shortening, causing shape and distortion and, in some cases, toughening of the product. Although the carcasses were electrically stimulated prior to roast removal, it appears that sufficient time had not elapsed between stimulation and cut removal for the attainment of a sufficiently low muscle pH to prevent muscle shortening. In addition, use of high cooking temperatures (68-80C) (Ray and Stiffler, 1979) appeared to accentuate muscle shortening and toughening.

The present study was designed to determine if muscle shortening and subsequent toughening would be reduced in a pre-rigor cooked product by allowing one hour between stimulation of the carcass and muscle excision, and by the use of low temperature - long time cookery. Cooking characteristics, microbiological aspects and storage stabilities were compared between pre-rigor and post-rigor cooked roasts.

MATERIALS AND METHODS

PAIRED sides of 15 Holstein cow carcasses (U.S. Utility, 270 kg) were used. One side was electrically stimulated with 500v (AC) for 20-2 sec pulses at 30 min post-exsanguination by placing probes in the neck and in the distal portion of the round. The current was supplied by a BOSS Hog Stunner, Model 1004E. The sides were then placed in a 0-1C cooler. One hour after stimulation, the top round portion (M. semimembranosus, M. adductor and M. gracilis) was removed from the electrically stimulated side of each carcass, fitted with a copper-constantan thermocouple in the approximate geometric center, vacuum packaged in a Cryovac^{R} B620 bag and submerged in a commercial cooking vat. The top round portion from the opposite side of the carcass was removed and handled in a similiar manner after the carcass had chilled for 24 hr.

The water in the cooking vat was maintained at 57.2C by the use of a pre-set steam regulator. Cooking procedure was according to that specified by USDA regulations for commercial production of rare, pre-cooked beef roasts (Angelotti, 1978), i.e., roasts were cooked until an internal temperature of 57.2C was attained and then held at this temperature for 37 min. Following cooking, the roasts were submerged in a slush-ice bath and chilled overnight.

The cooked, chilled roasts were unpackaged, weighed and measured for determination of cooking yields and dimensional changes. The roasts were cut into medial and lateral halves, vacuum packaged and the medial portion stored for 7 days and the lateral portion for 30 days at 0-1C. At the end of the storage period, the roasts were removed from the package and evaluated by a 3-member trained panel for surface discoloration using an 8-point scale (8=no surface discoloration; 5=10 to 25% discoloration; 1=100% discoloration) and for consumer desirability according to an 8-point scale (8=extremely desirable; 5=slightly desirable; 1=extremely undesirable). Weights were also obtained and compared to pre-packaging weights for determination of moisture (purge) loss during storage.

Twenty-five gram tissue samples were aseptically removed from the raw, cooked, handled (immediately after packaging for storage), 7 day stored and 30 day stored roasts. Tissue samples were placed in sterile Whirl-Pak^{R} bags and kept refrigerated until analyzed. Sample homogenates were prepared as indicated in the Compendium of Methods for the Microbiological Examination of Foods (1976). Serial (1:10) dilutions were prepared and 0.5 ml aliquots were pipetted directly onto the surface of prepoured plates of Plate Count agar (PCA, Difco) and spread using sterile bent glass rods. Duplicate plates were incubated at both 35C for 48 hrs and 7C for 10 days. Violet Red Bile agar (VRB, Difco) with 1% added glucose (VRBG) pour plates were prepared in duplicate using a 1.0 ml aliquot of each dilution and incubated at 35C for 24 hrs for enumeration of total Enterobacteriaceae.

Tissue samples were removed from the cut surface of the M. semimembranosus muscle for pH determination. Samples were obtained immediately before cooking, after cooking and after each storage period. Samples were frozen in liquid nitrogen, powdered, 2.5 g mixed with 25 ml of cold .005M sodium iodoacetate and the pH of the solution measured with a combination electrode on a Radiometer pH meter (Model PHM62). Sarcomere length was determined on samples removed after cooking and after the respective storage periods. Length determinations were made by the procedure described by Cross et al. (1980) utilizing a Spectra Physics Model 115 laser.

For shear force value determinations, a 3 cm section was removed from the cranial portion of each roast after the appropriate storage period. After the section reached room temperature, numerous 1.27 cm cores, parallel with the muscle fiber axis, were removed from the sections and sheared on a Warner-Bratzler Shear device.

To determine significance of difference between treatments, data were analyzed using the paired-t distribution analysis program of the Statistical Analysis System (Barr et al., 1979). Computing was done utilizing the facilities of the Northeast Regional Data Center of the State University System of Florida, Gainesville.

RESULTS AND DISCUSSION

A COMPARISON of cooking characteristics and dimensional changes in pre- and post-rigor cooked roasts are shown in Table 1. The internal temperature of the pre-rigor roasts at cooking was 37.6C while the post-rigor roasts had been chilled to 8C internally after 24 hrs at 0-1C. Pre-rigor roasts were heavier in both the raw and cooked states, but no difference (P>.05) in cooking loss was found. This difference in initial weight, even though the roasts were removed from contralateral sides, could be related to the ease with which muscles can be separated at their natural seams in the unchilled state. Cooking losses recorded for both treatment groups were low when compared to losses reported for roasts at higher temperatures (>10%) (Ray and Stiffler, 1979; Buck et al., 1979).

TABLE 1. COMPARISON OF COOKING CHARACTERISTICS AND DIMENSIONAL CHANGES OF PRE- AND POST-RIGOR COOKED TOP ROUND ROASTS

Trait	Treatment		Level of probability[a]
	Pre-rigor	Post-rigor	
Initial temperature, C	37.6	8.0	P<.0001
Raw weight, kg	7.8	7.5	P<.02
Cooked weight, kg	7.5	7.2	P<.01
Cooking loss, %	3.9	4.3	N.S.
Time to 57.2C, min	524.4	843.7	P<.0001
Overall cooking rate, min/kg[b]	67.8	112.7	P<.0001
Dimensional changes, %[c]			
Length	16.98	10.67	P<.005
Width	14.32	9.59	P<.02
Depth	-11.35	-6.25	N.S.

[a]Probability that the difference between treatments is statistically different based on the paired-t analysis. P>.05 was reported as nonsignificant (N.S.).
[b]Based on time to reach 57.2C internally.
[c]Calculated by comparing cooked measurements to raw measurements.

Time required to reach 57.2C internally was reduced (P<.0001) by approximately 316 min (>5 hr) when roasts were cooked from the pre-rigor rather than from the post-rigor state. Based on the time required to reach 57.2C internally, the overall cooking rate was 67.8 min/kg and 112.7 min/kg for pre-rigor and post-rigor cooked roasts, respectively. These differences in total cooking time and cooking rates reflect the time required to raise the temperature of post-rigor roasts from the chilled temperature (8C) to that of near body temperature (37.6C) of pre-rigor roasts.

Pre-rigor roasts exhibited a 16.98% reduction in length during cooking; whereas post-rigor roasts shortened only 10.67% (Table 1). A similiar trend was noted for changes in width during cooking (14.32% vs 9.5% for pre- and post-rigor roasts, respectively). No difference (P>.05) in depth changes was detected between the treatment groups. The dimensional change values for post-rigor roasts reflect normal changes that occur during cooking; the values for pre-rigor roasts suggest that muscle shortening had occurred. Both Cia and Marsh (1976) and Ray and Stiffler (1979) had reported that pre-rigor excised roasts or muscles underwent excessive shortening during cooking. However, the extent of shortening observed in this study was approximately one-half of that reported by Ray and Stiffler (1979). Perhaps shortening was reduced in this study by allowing an hour between carcass stimulation and roast removal during which time muscle pH was declining rapidly.

Storage stability characteristics and shear force values of treatment groups after 7 and 30 days of vacuumized storage at 0-1C are shown in Table 2. After both storage periods, purge (fluid) loss was approximately 1% less

TABLE 2. COMPARISON OF STORAGE STABILITY AND SHEAR FORCE VALUES OF PRE- AND POST-RIGOR COOKED TOP ROUND ROASTS

Day and Trait	Treatment		Level of probability[a]
	Pre-rigor	Post-rigor	
7 day storage			
Purge, %	6.6	7.6	P<.03
Surface discoloration[b]	6.5	5.7	P<.0004
Consumer desirability[c]	6.9	6.3	P<.007
Shear force value, kg	4.1	4.5	N.S.
30 day storage			
Purge, %	9.8	10.9	P<.02
Surface discoloration[b]	6.0	5.9	N.S.
Consumer desirability[c]	6.5	6.1	N.S.
Shear force value, kg	4.0	4.0	N.S.

[a]Probability that the difference between treatments is statistically different based on the paired-t analysis. P>.05 was reported as nonsignificant (N.S.).
[b]8=no discoloration; 1=100% surface discoloration.
[c]8=extremely desirable; 1=extremely undesirable.

for pre-rigor than for post-rigor cooked roasts. This difference may reflect an advantage in hydration capacity of proteins in muscle cooked from the pre-rigor state. Other workers have found that pre-rigor boned cuts held in the uncooked state had less purge loss than did post-rigor cuts (Cross et al., 1980). However, no data are available on purge loss during storage of pre-rigor boned and cooked roasts. Purge loss in both treatment groups was high and could be related to the large lean surface areas exposed when roasts were portioned for storage.

After 7 days of storage, pre-rigor cooked roasts received higher surface discoloration scores (less discoloration) and higher consumer desirability scores than did post-rigor cooked roasts. This discoloration involved lean surface exposed after cooking and portioning and was judged to be a brown, or oxidized, discoloration. After 30 days of storage, no differences (P>.05) in storage stability were detected between treatment groups. Two roasts, one in each group, were determined to be slightly undesirable after 30 days of storage.

No differences in shear force values were detected between treatments after either 7 or 30 days of storage (Table 2). The mean shear force values of 4.5 and 4.0 kg for post-rigor and pre-rigor cooked roasts, respectively, after 7 days of storage and 4.0 kg for both treatments groups after 30 days of storage indicate that tenderness was acceptable. Since Ray and Stiffler (1979) detected severe toughening of roasts that were removed from the carcass immediately after electrical stimulation and cooked in 68 to 80C water, the lack of differences in shear force values found in the present study could be related either to the holding time between stimulation and boning or the use of the low temperature-long time cookery method. Buck et al. (1979) reported that low temperature water bath cookery resulted in more tender roasts than did conventional oven cookery. However, Marsh (1977) suggested that there appears to be a critical heating rate for cooking of pre-rigor roasts. He indicated that the heat treatment should be sufficiently fast to cause enzyme denaturation before significant progress toward rigor has been made thereby resulting in a tender, but distorted, product.

Muscle pH at the initiation of cooking was higher (P<.001) for the pre-rigor roasts (6.31) than for the post-rigor roasts (5.51) (Table 3). This higher pH of the pre-rigor cooked product was also found after cooking and after storage for 7 and 30 days. During the cooking process, the pH of the pre-rigor roasts declined while that of the post-rigor roasts increased. Thus, the pre-rigor roasts must have undergone some glycolytic activity during the initial heating period prior to enzyme denaturation.

Sarcomere lengths of pre-rigor cooked samples were shorter (P<.0001) at all evaluation times than post-rigor cooked samples (Table 3). The extremely short sarcomere lengths (<1.5 μ) of pre-rigor cooked roasts suggest extreme muscle shortening as was reflected by the observed changes in dimensional measurements. Even with this extreme shortening, tenderness was not reduced as had been reported earlier by Marsh (1977). According to George et al. (1980), the tenderizing effect of electrical stimulation can be attributed to the low ph/high temperature relationship occurring in the muscle at rigor onset. The higher than normal temperature maintained in the pre-rigor muscle by the conditions of the present study may have accentuated the tenderizing effect of electrical stimulation.

TABLE 3. COMPARISON OF MUSCLE pH AND SARCOMERE LENGTH OF PRE- AND POST-RIGOR COOKED TOP ROUND ROASTS

Trait and Time	Treatment		Level of probability[a]
	Pre-rigor	Post-rigor	
pH			
Raw	6.31	5.51	P<.0001
Cooked	6.17	5.91	P<.0001
After storage - 7d	6.01	5.95	P<.008
After storage - 30d	5.84	5.77	P<.007
Sarcomere length, μ			
Cooked	1.30	2.03	P<.0001
After storage - 7d	1.49	1.98	P<.0001
After storage - 30d	1.36	2.00	P<.0001

[a]Probability that the difference between treatments is statistically different based on the paired-t analysis.

Means of log counts (log_{10}/g) for mesophilic aerobic plate counts (APC-35), psychrotrophic plate counts (APC-7) and total Enterobacteriaceae counts (VRBG) from raw, cooked, handled and 7 and 30 day stored roasts are presented in Table 4. No differences (P>.05) between treatment groups for aerobic plate counts were detected at any sampling period. For both pre-rigor and post-rigor cooked roasts, total counts (APC's) decreased with cooking and increased during handling and storage for 30 days. After 30 days of storage, APC's at 7 and 35C had increased by approximately 6 logs, probably due to the growth of facultative anaerobes under vacuum package conditions.

Total Enterobacteriaceae counts were significantly higher at all time periods, except after cooking, for post-rigor cooked roasts than for pre-rigor cooked roasts (Table 4). These counts increased as storage time increased.

TABLE 4. COMPARISON OF TOTAL AEROBIC PLATE COUNTS (APC) AND TOTAL ENTEROBACTERIACEAE (VRBG) COUNTS (log_{10}/g FOR PRE- AND POST-RIGOR TOP ROUND ROASTS

Time and Type	Treatment		Level of probability[a]
	Pre-rigor	Post-rigor	
Raw roasts			
APC-7	1.92	2.65	N.S.
APC-35	3.03	3.78	N.S.
VRBG	0.71	1.15	P<.02
Cooked roasts			
APC-7	0.68	0.86	N.S.
APC-35	1.90	1.88	N.S.
VRBG	0.48	0.48	N.S.
Handled roasts			
APC-7	1.64	1.90	N.S.
APC-35	3.27	3.15	N.S.
VRBG	0.53	1.12	P<.0003
Stored roasts - 7 days			
APC-7	1.72	1.93	N.S.
APC-35	2.55	2.56	N.S.
VRBG	0.79	2.06	P<.0003
Stored roasts - 30 days			
APC-7	7.45	7.72	N.S.
APC-35	7.59	7.44	N.S.
VRBG	3.95	6.08	P<.0009

[a]Probability that the difference between treatments is statistically different based on the paired-t analysis. P>.05 was reported as nonsignificant (N.S.).

SUMMARY

COMBINING electrical stimulation (500v, 20-2 sec pulses), a conditioning period and low temperature - long time cookery of pre-rigor top round beef roasts resulted in a product comparable to post-rigor cooked product in terms of storage stability, tenderness and microbial quality. Muscle shortening and shape distortion were encountered in the pre-rigor product. Cooking time, and thus energy required, was reduced to approximately 40%.

REFERENCES

Angelotti, R. 1978. Cooking requirements for cooked beef and roast beef. Fed. Register 43: 30791.

A.P.H.A. Compendium Of Methods For the Microbiological Examination of Foods. 1976. Washington, D.C.

Barr, A. J., J. H. Goodnight, J. P. Sall, W. H. Blair and D. M. Chilko. 1979. Statistical Analysis System User's Guide. Eds. Helwig, J. T. and K. A. Council. SAS Institute, Inc., Raleigh, N.C.

Buck, E. M., A. M. Hickey and J. Rosenau. 1979. Low-temperature air oven vs a water bath for the preparation of rare beef. J. Food Sci. 44: 1602.

Cia, G. and B. B. Marsh. 1976. Properties of beef cooked before rigor onset. J. Food Sci. 41: 1259.

Cross, H. R., J. Tennent and D. Muse. 1979. Storage properties of hot and cold-boned beef cuts. J. Anim. Sci. (In Press).

Cross, H. R., R. L. West and T. R. Dutson. 1980. A comparison of methods for measuring sarcomere length in beef semitendinosus muscle. Meat Sci. (In Press).

George, A. R., J. R. Bendall and R. C. D. Jones. 1980. The tenderizing effect of electrical stimulation of beef carcasses. Meat Sci. 4: 51.

Marsh, B. B. 1977. Temperature and postmortem change: Energy use and meat quality. Proc. Meat Ind. Res. Conf. Amer. Meat Inst. Found. Chicago, IL. p. 13.

Ray, E. E. and D. M. Stiffler. 1979. Hot boning of beef as a means of conserving energy. Livestock Res. Cattle Growers Short Course, New Mexico State Univ. p. 21.