K-1

EFFECTS OF HOT-BONING AND COOKING METHODS UPON COOKING TIME AND LOSSES, AND TENDERNESS OF ROASTS FROM ELECTRICALLY STIMULATED BEEF CARCASSES

E. E. RAY[1], D. M. STIFFLER[1], and B. W. BERRY[2]

[1]New Mexico State University, Las Cruces, New Mexico, U.S.A.

[2]Meat Science Research Lab., FR-SEA,USDA, Beltsville, Maryland, U.S.A.

INTRODUCTION

ENERGY demands by the meat industry are the largest among the food industries; however, meat firms have reduced energy consumption by 4% while increasing productivity by 24% from 1972 to 1978 (Meat Industry, 1979). Continued conservational efforts relative to energy utilization is essential to the survival of the meat industry. Accelerated processing by hot boning of muscles and prerigor cooking prior to chilling is one such conservation method that saves energy by: 1) increased efficiency; 2) reducing the requirements for refrigeration facilities and chilling time; 3) reducing transportation cost; and 4) reducing needed labor. Removal of muscles and muscle systems prior to chilling the bovine cascass has been investigated (Schmidt and Gilbert, 1970; Kastner et al., 1973; Schmidt and Keman, 1974; Kastner and Russell, 1975; Henrickson, 1975) to determine the feasibility of this method as an alternative to conventional fabrication. Numerous studies (Moran and Smith, 1929; Ramsbottom and Strandine, 1948; Paul et al. 1952; deFremery and Pool, 1960; Marsh, 1964; Weideman et al., 1967; Cia and Marsh, 1976) have shown that meat cooked immediately after rigor mortis is relatively tough, whereas meat cooked before the onset of rigor mortis is relatively tender depending on rate of heating. They also observed an appreciable shape change accompanying the cooking of prerigor meat, which could have a pronounced influence upon consumer acceptance of this product.

Cia and Marsh (1976) reported that reprigor cooked product (bovine sternomandibularis) shortened to a remarkable extent, yet suffered less cooking loss and was considerably more tender than in-rigor meat. Paul et al. (1952) observed that deep-fried steaks were more tender from prerigor than in-rigor meat, but the opposite was noted when steak was roasted. Electrical stimulation could be used to increase the feasibility of accelerated processing. Gilbert and Davey (1976) suggested reduced chilling requirements necessary to achieve carcass setting, less cold shortening and additional tenderizing from aging would reduce aging and chilling time necessary to produce an acceptable product. Incentives to develop a prerigor cooking process appear to be reduced cooking losses, a major reduction in processing time and reduced chilling requirements and facilities for the raw product. The cooking process requires considerably less energy input since the inherent heat of the muscle would be utilized. Certain deterrants appear to be conflicting results concerning product palability, shape distoration and the inability to quality grade (USDA) such products.

This study was initiated to examine effects of hot-boning and method of cooking upon physical shape, cooking yield, length of cooking period and shear force values of roasts from the semimembranosus and semitendinosus beef muscles of electrically stimulated carcasses.

MATERIALS AND METHODS

THIRTY USDA Good and Standard grade Mor-Lean cattle, with an average live slaughter and hot carcass weight of 490 and 316 kg., respectively, were used. Mor-Lean cattle have their scrotum shortened by moving the testicles near the animal's body and securing in place by stretching an elastrator ring over the scrotum below the testicles which results in a portion of the scrotum sloughing off. All sides were electrically stimulated (100 impulses, 1 sec duration, 110 volts, < 5 amps) within 1 hr post-stunning and prior to chilling using a pulse generator. The semimembranosus and semitendinosus muscles were removed from one side within 1.5 hr post-exsanguination while the same muscles from the matched side were removed 7 days 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 weighed, temperature monitored, measured for length, width (at 25.0, 50.0 and 75.0% of the length) and depth at the deepest point of the muscle.

Muscles were rubbed with a commercial roast beef preparation to simulate commercial roast beef, placed into a Cryovac® bag (L600), vacuumized (Multivac®) and cooked to an internal temperature of 68°C with steam, hot water vat or convectional electric oven (Blodgett®). Internal roast temperature was monitored during cooking with temperature probes. The cooking schedule was: 1st hr at 68°C; 2nd hour at 74°C; and the remaining time at 80°C. Subsequent to cooking, cooking time was recorded and the product was chilled to 38-40°C. The same measurements were made as those prior to cooking and a 3.8 cm thick sample was removed from the center portion of each roast for Warner-Bratzler shear (WBS) determination. Three cores from each sample were sheared and all cores were sheared twice. Cooking yield was determined by the difference in weight of the raw and cooked product. Cooking loss was determined as the difference in weight between the raw muscle plus seasonings and cooked weight of the roast.

Data were analyzed by the statistical procedures described by Steel and Torrie (1960), with a paired-t distribution analysis to determine significance of difference between pre- and postrigor roasts. Analysis of variance was used to evaluate differences in method of cookery.

RESULTS

MEANS for the linear measurements by muscle, time of postmartem boning and cooking method are presented in Table 1. Method of cookery appear to have no influence ($P < 0.05$) on the changes in linear measurements regardless of muscle or time of postmortem boning. The steam oven cooked ST muscle showed the least change but was not significantly different. Therefore, pooled main effect means for percent change in these measurements are presented in Table 2. These data indicate HB roast shortened more ($P < 0.01$) than CB for both the ST (28.8 vs 14.3%) and SM (43.6 vs 23.9%) muscles. Cia and Marsh (1976), using bovine sternomandibularis samples, reported a 50.4% reduction in length when the samples were cooked 0.7 to 3.1 hr postmortum. Minimal changes in width were noted (Table 2). Differences ($P < 0.05$) in roast depth were observed between temperature of boning and muscle. CB roast from ST showed less change in depth (2.9 vs 11.9%) than those from the SM. Changes in depth among muscles for HB roast were more pronounced. It is apparent from these data that the observed decrease in the length of HB roast were accompanied by a similar increase in depth, or thickness of the cooked product. Differences between mucles can most likely be explained by the fact that the ST muscle represented an intact muscle, whereas, the SM was longitudinally split which would result in it being more susceptible to shape changes.

It is evident that there are greater changes associated with the HB product which has been cited as a possible disadvantage for fresh HB product because possible problems in further fabrication to steaks and roasts. This distortion of shape becomes of less concern when dealing with a pre-cooked product rather than a fresh product.

The time required to cook roasts was divided by their cooked weights (Table 3). Time per unit weight to cook HB roasts was similar for ST and SM muscles within each method of cooking. Cooking HB roasts in a hot water vat required significantly ($P < 0.05$) less time per unit weight than cooking with steam or convectional electric ovens. More variation was observed in time per unit weight required to cook CB roasts for the ST than the SM. However, hot water vat cooking required less ($P < 0.05$) time per unit weight than steam and convectional electric ovens. HB roasts required 28% and 29% ($P < 0.05$) less cooking time per unit weight than CB roasts of ST and SM muscles, respectively. Montgomery et al. (1977) reported hot processed pork roasts to have a 9% advantage in cooking time per kg of raw roast over the cold processed roast.

Cooking loss (Table 3) was somewhat influenced ($P < 0.05$) by method of cookery. ST roasts (HB and CB) cooked in the convectional electric oven had the highest ($P < 0.05$) cooking losses, whereas method of cookery had no influence on cooking losses for the SM. HB roasts from both muscles had lower ($P < 0.05$) cooking losses than CB roasts. Cia and Marsh (1976) reported cooking losses (percent of raw weight) of 18%, 22.8%, 24.9% and 26.8% for muscles removed 2.4, 4.9, 8.6 and 37 hr postmortem, respectively.

Shear force value was influenced by both the time of postmortem boning and cooking method (Table 4). HB roast were determined to be consistently less tender ($P < 0.01$) than the CB roast (50% differences). This is in aggreement with the report of Weiner et al. (1966) and Montgomery et al. (1977). Hot water vat cookery resulted in the greatest reduction in shear force. ST muscle had a 63.7% reduction when cooked utilizing a hot

Table 1. Linear measurements of roasts from the semitendinosus and semimembranosus muscles according to temperature of postmortem boning and method of cooking.

	Method of cooking and boning					
	Steam oven		Hot water vat		Convectional electric	
Item	Cold-boned	Hot-boned	Cold-boned	Hot-boned	Cold-boned	Hot-boned
No. of roasts	10	10	10	10	10	10
Semitendinosus						
Fresh muscle:						
Length, cm	$35.1^{a}\pm.4$	$31.5^{a}\pm.4$	$35.9^{a}\pm.6$	$32.1^{a}\pm.9$	$35.2^{a}\pm.9$	$33.2^{a}\pm.8$
Width, cm	$11.6\pm.3$	$14.0\pm.5$	$12.0\pm.3$	$13.9\pm.5$	$12.4\pm.2$	$14.2\pm.4$
Depth, cm	$8.2\pm.2$	$7.8^{a}\pm.2$	$8.5\pm.3$	$9.2^{a}\pm.3$	$8.5\pm.2$	$8.9^{a}\pm.2$
Cooked product:						
Length, cm	$29.1^{b}\pm.5$	$24.4^{b}\pm.5$	$29.6^{b}\pm.4$	$25.0^{b}\pm.5$	$29.9^{b}\pm.6$	$25.7^{b}\pm.8$
Width, cm	$11.1\pm.2$	$14.3\pm.3$	$11.2\pm.2$	$14.5\pm.3$	$11.4\pm.2$	$14.4\pm.5$
Depth, cm	$8.2\pm.2$	$9.8^{b}\pm.3$	$8.9\pm.3$	$10.8^{b}\pm.3$	$8.8\pm.2$	$10.6^{b}\pm.4$
Semimembranosus						
Fresh muscle:						
Length, cm	$34.3^{a}\pm.5$	$36.7^{a}\pm.9$	$36.3^{a}\pm.9$	$37.0^{a}\pm.9$	$35.1^{a}\pm.7$	$37.5^{a}\pm1.1$
Width, cm	$11.2^{a}\pm.4$	$13.1^{a}\pm.7$	$11.6\pm.2$	$11.8\pm.4$	$12.5\pm.6$	$12.3^{a}\pm.4$
Depth, cm	$7.8^{a}\pm.4$	$8.6^{a}\pm.6$	$8.5\pm.3$	$8.6^{a}\pm.3$	$8.8\pm.5$	$8.2^{a}\pm.3$
Cooked product:						
Length, cm	$28.4^{b}\pm.6$	$26.3^{b}\pm.8$	$28.3^{b}\pm.3$	$25.3^{b}\pm.6$	$28.8^{b}\pm.7$	$26.0^{b}\pm.7$
Width, cm	$10.2^{b}\pm.6$	$11.9^{b}\pm.7$	$10.6\pm.4$	$11.1\pm.4$	$11.0\pm.5$	$11.2^{b}\pm.6$
Depth, cm	$9.1^{b}\pm.5$	$12.4^{b}\pm.7$	$9.3\pm.4$	$12.1^{b}\pm.3$	$9.7\pm.5$	$11.7^{b}\pm.6$

[a,b] Means for the same item in the same column, within muscles and postmortem boning temperatures, with different superscripts differ significantly ($P < 0.05$).

Table 2. Changes in linear measurements of roasts from the semitendinosus and semimembranosus muscles as influenced by method of postmortem boning.

Item	Semitendinosus Cold-boned	Semitendinosus Hot-boned	Semimembranosus Cold-boned	Semimembranosus Hot-boned
No. of roasts	30	30	30	30
Change in (fresh vs cooked):				
Length, %	$-14.3\pm.6^{a}$	$-28.8\pm.7^{b}$	$-23.9\pm.6^{a}$	$-43.6\pm.6^{b}$
Width, %	$-11.7\pm.3^{a}$	$+2.9\pm.3^{b}$	$-9.4\pm.5$	$-8.8\pm.5$
Depth, %	$+2.9\pm.2^{a}$	$+20.8\pm.2^{b}$	$+11.9\pm.4^{a}$	$+42.8\pm.5^{b}$

[a,b]Means in the same row, within muscles, with different superscripts differ significantly ($P < 0.05$).

Table 3. Influence of method of cooking and postmortem boning upon total cooking time and losses of beef roasts.

Item	Method of Boning	Method of Cooking: Steam	Hot Water Vat	Convectional Electric
SEMITENDINOSUS				
Cooking time/kg, min	HB	$92.7\pm4.0^{a,c}$	$71.5\pm3.1^{a,d}$	$113.3\pm4.7^{a,e}$
	CB	$113.1\pm4.4^{b,c}$	$87.2\pm3.8^{b,c}$	$155.2\pm5.8^{b,e}$
Cooking loss, %	HB	$12.4\pm.09^{a,c}$	$13.5\pm.08^{a,c}$	$15.4\pm.18^{a,d}$
	CB	$19.1\pm.23^{b,c}$	$20.2\pm.19^{b,c}$	$22.5\pm.23^{b,d}$
SEMIMEMBRANOSUS				
Cooking time/kg, min	HB	$87.8\pm3.3^{a,c}$	$79.1\pm3.4^{a,d}$	$114.7\pm6.9^{a,e}$
	CB	$123.0\pm5.3^{b,c}$	$101.7\pm4.5^{b,d}$	$139.5\pm7.1^{b,e}$
Cooking loss, %	HB	$14.9\pm.12^{a}$	$16.0\pm.14^{a}$	$16.2\pm.16^{a}$
	CB	$21.7\pm.13^{b}$	$22.1\pm.27^{b}$	$22.1\pm.33^{b}$

a,b Means in the same column, within an item, postmortem boning time and muscle, with different superscripts differ significantly ($P < 0.05$).

c,d,e Means in the same row with different superscripts differ significantly ($P < 0.05$).

water vat.

Several workers (Paul et al., 1952; and Cia and Marsh 1976) have reported increased tenderness of pre-rigor/postmortem cooked sternomandibularis muscles to that cooked after rigor onset was a function of differences in pH and shattering of fiber structure brought about by extreme shortening. Marsh (1977) postulated that there exists a critical heating rate if reached will provide improved tenderness in association with pre-rigor treatments. Paul et al. (1952) accomplished this with deep-fat frying compared to oven roasting and Cia and Marsh (1976) compared microwave cookery and boiling water, both having a high rate of heat induction.

The temperatures used in this study for cooking of roasts (1st hr at 68°C; 2nd hr at 74°C; 3rd hr and longer at 80°C) were certainly below the critical heating rate needed to arrest the rigor process, which may have resulted in a heat induced rigor. This can be related to changes in linear measurements and the resultant reduction in tenderness. Montgomery et al. (1977) observed that the greater the state of contracture at rigor, the greater the toughness. Several workers (Locker, 1960; Herring et al., 1965; Howard, 1968; Welbourn et al., 1968; and McCrae et al., 1971) have reported that a muscle is tougher if it enters rigor in the contracted state. There is no doubt tenderness is an important concern; however, considering most product merchandizing under such a system would be served as thinly sliced product, shear force determination may not be the most applicable method to elucidate tenderness differences.

CONCLUSION

RESULTS of this study indicate significant changes in certain linear measurement associated with shape distortion, a reduction in cookery time which could result in appreciable energy savings and higher cooking yields for ST and SM muscles removed early postmortem and cooked prior to rigor onset compared to similar muscles removed subsequent to a 7 day aging and chilling period. However, a rather larger increase in shear force was noted for the HB compared to the CB muscles. Cookery method was determined to have minimal influence on this characteristic, with the exception of cooking time and tenderness. Hot water vat cookery appeared to provide the most efficient cookery rate/kg, but resulted in the greatest decrease in tenderness. Tenderness appears to be associated with heating rate, then, there is an apparent need to determine optimum temperatures and scheduling endpoints for cooking hot-boned meat relative to a particular cooking method.

Table 4. Shear force[a] means (kg) as influenced by muscle, method of cooking and postmortem boning.

Method of Cooking	Semitendinosus Cold-boned	Semitendinosus Hot-boned	Semimembranosus Cold-boned	Semimembranosus Hot-boned
No. of roasts	30	30	30	30
Steam oven	3.73±.17[b]	6.00± .50[c,d]	3.89±.46[b]	6.43±.62[c,d]
Hot water vat	3.74±.27[b]	10.31±3.52[c,e]	4.12±.51[b]	8.53±.68[c,e]
Convectional electric oven	3.50±.10[b]	6.00± .49[c,d]	3.74±.25[b]	7.39±.54[c,d]

[a]Warner-Bratzler shear, kg/1.27 cm.
[b,c]Means in the same row, within a muscle, with different superscripts differ significantly ($P < 0.05$).
[d,e]Means in the same column, within method of boning, with different superscripts differ significantly ($P < 0.05$). (Comparison of method of cookery).

REFERENCES

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

Cross, H. R. 1979. Effects of electrical stimulation on meat tissue and muscle properties -- a review. J. Food Sci. 44:509.

Gilbert, K. V. and Davey, C. L. 1976. Carcass electrical stimulation and early boning of beef. N. Z. J. of Agri. Res. 19.

deFremery, D. and Pool, M.F. 1960. Biochemistry of chicken muscle as related to rigor mortis and tenderization. Food Res. 25:73.

Henrickson, R. L. 1975. Hot-boning. Presented Meat Ind. Res. Conf., University of Chicago.

Herring, H. K., Cassens, R. G. and Briskey, E. J. 1965. Further studies on bovine muscle tenderness as influenced by carcass position, sarcomere length and fiber diameter. J. Food Sci. 30:1049.

Howard, R. D. and Judge, M. D. 1968. Comparison of sarcomere length to other predictors of beef tenderness. J. Food Sci. 33:456.

Kastner, C. L., Henrickson, R. L. and Morrison, R. D. 1973. Characteristics of hot boned bovine muscle. J. Anim. Sci. 36:484.

Kastner, C. L. and Russell, T. S. 1975. Characteristics of conventionally and hot-boned bovine muscle excised at various conditioning periods. J. Food Sci. 40:747.

Locker, R. H. 1960. Degree of muscular contraction as a factor in tenderness of beef. Food Res. 25:304.

Marsh, B. B. 1964. Meat quality and rigor mortis. In "Carcass Composition and Appraisal of Meat Animals". Paper No. 12, CSIRO, Australia.

Marsh, B. B. 1977. Temperature and postmortem change: energy use and meat quality. Proc. Meat Ind. Res. Conf. (A.M.I.F., Chicago) p. 13.

McCrae, S. E., Seccombe, C. G., Marsh, B. B. and Carse, W. A. 1971. Studies in meat tenderness. 9. The tenderness of various lamb muscles in relation to their skeletal restraint and delay before freezing. J. Food Sci. 36:566.

Meat firms report savings to Energy Department, 22% cut in BTU's per pound. 1972-1978. 1979. Meat Industry 26:72.

Montgomery, T. H., Ramsey, C. B. and Lee, R. W. 1977. Microwave and conventional precooking of hot and cold processed pork loins. J. Food Sci. 42:310.

Moran, T. and Smith, E. C. 1929. Postmortem changes in animal tissues. The conditioning or ripening of beef. Special Rep. No. 36, Food Invest. Board, London.

Paul, P. C., Bratzler, L. J., Farwell, E. D. and Knight, K. 1952. Studies on tenderness of beef. 1. Rate of heat penetration. Food Res. 17:504.

Ramsbottom, J. M. and Strandine, E. J. 1948. Comparative tenderness and identification of muscles in wholesale beef cuts. Food Res. 13:315.

Schmidt, G. R. and Gilbert, K. V. 1970. The effect of muscle excision before the onset of rigor mortis on the palatability of beef. J. Food Technol. 5:331.

Schmidt, G. R. and Keman, S. 1974. Hot boning and vacuum packaging of eight major bovine muscles. J. Food Sci. 39:140.

Steel, R. G. D. and Torrie, J. H. 1960. "Principles and Procedures of Statistics". McGraw-Hill Book Co., New York, N. Y.

Weidemann, J. F., Kaess, G. and Curruther, L. D. 1967. The histology: prerigor and postrigor ox muscle before and after cooking and relation to tenderness. J. Food Sci. 32:7.

Weiner, P. D., Kropf, D. H., Mackintosh, D. L. and Koch, B. A. 1966. Effect on muscle quality of processing pork carcasses within one hour postmortem. Food Technol. 20:541.

Will, P. A., Henrickson, R. L. and Morrison, R. D. 1976. The influence of delay chilling and hot boning on tenderness of bovine muscle. J. Food Sci. 41:1102.

Welbourn, J. L., Harrington, R. B. and Stadelman, W. J. 1968. Relationships among shear values, sarcomere lengths and cooling procedures in turkeys. J. Food Sci. 33:450.