EFFECT OF INDIVIDUAL MUSCLES AND CONNECTIVE TISSUE LEVELS ON THE SENSORY AND SHEAR PROPERTIES OF RESTRUCTURED BEEF STEAKS

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ABSTRACT

Restructured steaks were made from slices of forequarter muscles known to be different in tenderness. Additional steaks were made from pieces that were sorted to contain either epimysium, intramuscular connective tissue sheets or no visible connective tissue. Texture panels and shear force values could discriminate between steaks from some of the different muscles. High correlations ($P < 0.05$) existed between connective tissue amounts and the sensory evaluations of residual connective tissue toughness and instrumental shear force values.

INTRODUCTION

Restructured beef steaks have been made with acceptable binding, color and flavor, but when made from large meat particles from more economical portions of the carcass, such as the chuck, they had an unacceptable texture (Booren *et al.* 1981; Berry *et al.* 1986a,b; Berry *et al.* 1988). Upon mastication, an objectionable residue of connective tissue remained in the mouth. Extensive hand trimming of connective tissues has been deemed uneconomical (Recio *et al.* 1986).

Strange and Whiting (1990) quantitatively separated the connective tissues of beef chuck (tendon, epimysium, and gristle) and returned known quantities of them or a peri/endomysial extract into restructured steaks. Sensory and shear values indicated a relatively minor contribution by the perimysium/endomysium to residual toughness. The quantities of epimysium or gristle were significantly correlated to the panelist's perception of connective tissue toughness and shear force values of uncooked steaks. Relatively low amounts of tendon were readily detectable.

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The intent of this study was to determine the sensory texture scores and Kramer shear from values of restructural beef steaks made from different forequarter muscles that had been trimmed of visible connective tissue. A second set of steaks was made that contained epimysial and intramuscular connective tissues to correlate connective tissue contents with sensory scores and shear force values.

MATERIALS AND METHODS

Product Manufacture

USDA choice chucks (yield grade 2) and ribeyes were obtained from a local wholesaler and held under refrigeration (6 °C). The *Rhomboideus, Serratus ventralis, Triceps brachii, Longissimus dorsi* (ribeye), *Supraspinatus,* and *Infraspinatus* muscles were removed and trimmed of adipose tissues and tendons.

For the first experiment, *epimysium* and thick sheets of intramuscular connective tissue (ICT) were trimmed off of *Rhomboideus, Serratus ventralis, Triceps brachii,* and *Longissimus dorsi* muscles, which were cut into large (ca 200 g) chunks and frozen at −18 °C. The chunks were then tempered and cut (3 mm) perpendicular to the fiber direction with a meat slicer (Globe Slicing Mach. Co., Stanford, Conn., Model 110). These slices were hand cut into approximately 1 cm square flakes. To obtain enough product flakes, the *Serratus ventralis* and *Triceps brachii* muscles were combined. The flakes were mixed with 0.75% NaCl and 0.12% sodium tripolyphosphate (Wilcox and Hofstad 1970; Schwartz and Mandigo 1976) for 2 min in a Hobart mixer. They were packed into aluminum baking pans, vacuum sealed, refrigerated for 4 h, and frozen (−20 °C). These operations were conducted in a meat processing room at 11 °C. Within 1 week they were tempered, sliced (2.5 cm thick), vacuum packaged, and refrozen. This procedure was repeated using a second lot of raw material.

For the second experiment, the *Supraspinatus* and *Infraspinatus* muscles were frozen, tempered and sliced (3 mm) perpendicularly to the fiber direction. They were cut by hand into flakes (approximately 1 cm square) which were sorted according to whether the flakes possessed epimysium, ICT, or neither. These flakes were made into restructured steaks as described above. This procedure was repeated using another lot of raw material.

Analyses

Protein, fat, and water content of the restructured steaks were determined by Tecator Kjeldahl, Soxlet, and oven drying, respectively (AOAC 1984). The pH was measured after blending 2.5 g restructured steak in 22.5 mL water. Sarcomere lengths were determined by fixing small pieces of muscle in 2%

glutaraldehyde, separating fiber bundles and measuring them by laser diffraction (Ruddick & Richards 1975). Connective tissue (collagen) was estimated by four determinations using the hydroxyproline assay of Woessner (1961) on ground and then homogenized (Brinkman polytron tissue grinder) samples (Strange and Whiting 1990).

Shear values were determined using the multi-blade Kramer cell in the Instron Universal Testing Machine. Restructured steaks were cut into six portions (ca 25 g), thawed and weighed. The uncooked samples were sheared at 50 mm/min crosshead speed and 500 kg full scale (Booren *et al.* 1981). Previous research revealed that connective tissue levels were better quantitated on raw rather than cooked restructured steaks (Strange and Whiting 1988). Shear force values were calculated as Newtons per gram of steak.

Sensory evaluations of texture were conducted in conjunction with evaluations described previously (Strange and Whiting 1990). Steaks were cooked (immediately before being evaluated) on a Farberware open hearth grill to an internal temperature of 70 °C with one turning and served warm. Sensory testing was by a 16-member, trained panel (Cross *et al.* 1978) over four consecutive mornings in the order, experiment 1-lot 1, experiment 2-lot 1 to experiment 2-lot 2. Panelists were presented coded samples while seated in individual booths under red lighting. Samples were scored on a 10.0 cm unstructured line for initial tenderness (10 = very tender), connective tissue (10 = no detectable connective tissue), and overall textural impression (10 = like extremely).

A two-way analysis of variance and Duncan's multiple range test were employed using raw material lots as the block (Steel and Torrie 1960). Correlation coefficients were determined between variables in Experiment 2.

RESULTS AND DISCUSSION

Selection of muscles was based on work by Ramsbottom and Strandine (1948), McKeith *et al.* (1985) and Paterson and Parrish (1986). The *Rhomboideus* muscle contains high amounts of connective tissue and lacks tenderness. The *Longissimus dorsi* muscle has the opposite characteristics and *Triceps brachii* and *Serratus ventralis* muscles are intermediate in tenderness and connective tissue amount. The *Infraspinatus* muscle is a tender muscle, while the *Supraspinatus* muscle lacks tenderness; however, both muscles have a heavy epimysium cover over the surface not attached to the shoulder blade and a major sheet of ICT that runs most of the length of the muscle. Costello *et al.* (1981) and Noble *et al.* (1985) demonstrated that good textured, restructured steaks could be made using slices of meat rather than chunks.

There were no important differences in the composition, sarcomere length or pH values of the three treatments in Experiment 1 (Table 1). Epimysium and

TABLE 1.

PROPERTIES OF RESTRUCTURED STEAKS MADE FROM DIFFERENT MUSCLES

	Longissimus	*Serratus-Triceps*	Rhomboideus	$S_{\bar{x}}$
Composition				
% Protein	20.9	20.1	20.0	
% Fat	6.6	6.5	6.6	
% Water	70.0	71.0	69.9	
Sarcomere Length (μ)	1.8	2.0	2.0	
pH	5.8	5.9	5.9	
Shear Force (N/g)	25^a	40^b	64^c	3.3
Collagen (μg Hyp/mg)	0.80^a	0.78^a	1.82^b	0.05
Sensory Panel				
Initial Tenderness	7.8^a	7.4^a	6.0^b	0.40
Connect. Tissue	8.4^a	8.0^a	6.3^b	0.31
Overall Texture	7.6^a	7.5^a	5.9^b	0.33

Values in a row with the same superscript are not different ($P > 0.05$)
$S_{\bar{x}}$ Standard error of the treatment means
Sensory Scores 0 Low; 10 High for initial tenderness, absence of connective tissue and overall texture

ICT had been trimmed from all of these muscles, so that the textural differences were the result of myofibrillar and peri-/endomysial effects.

The shear force values in Table 1 indicated the expected decreases in tenderness of steaks made from the *Longissimus* to *Serratus-Triceps* and to *Rhomboideus* muscles. The hydroxyproline content was not different ($P > 0.05$) between the first two muscles but was greater ($P < 0.05$) in the *Rhomboideus* muscle. The sensory panels scored steaks from the *Rhomboideus* muscle lower ($P < 0.05$) for all three textural traits. The decreased initial tenderness and connective tissue scores for *Rhomboideus* steaks suggested that the intramuscular

connective tissue components do play a role in determining the texture of restructured products. The absence of differences in sarcomere length and pH does not support postmortem myofibrillar events as being the cause of the textural differences. The sensory panel scores were all high for steaks made from these muscles-even steaks from the *Rhomboideus* muscle were above the midpoint of the sensory scales.

Differences ($P < 0.05$) were found between the steaks made from flakes with epimysium or ICT and those made from flakes with neither connective tissue (Table 2). Protein composition and pH were not affected by the sorting. Hydroxyproline values for the steaks with epimysium and ICT were higher than those for steaks in Table 1. In contrast to the previous experiment, the initial tenderness scores were not consistently affected by the treatments. Therefore, the initial bites were not sensitive to large particles of connective tissue. The connective tissue scores were lowered ($P < 0.05$) by the presence of the connective tissues and the shear force values were increased ($P < 0.05$). The overall texture scores illustrated the importance that the panel placed on the residual connective tissue in evaluating this product. The restructured steaks in the experiment contained connective tissues in their normal configuration in contrast to the steaks made by Strange and Whiting (1990) where the connective tissues were first removed and then readded.

The correlation coefficients from Experiment 2 are in Table 3. Significant correlations were found between hydroxyproline content and both connective tissue scores ($P < 0.05$) and shear force values ($P < 0.01$) of raw steaks. These correlations were significant as a result of our steaks in Experiment 2 being made so that connective tissue was the major variable. However, it clearly demonstrated the relationship between connective tissue content and texture.

The relationship between hydroxyproline content and sensory connective tissue scores were similar to those reported by Strange and Whiting (1990) where the restructured steaks were made with 6 to 12 mm cubes of trimmed chuck and 0.5 cm particles of isolated connective tissue that were added back to the product. In these experiments, the epimysium and gristle were in their native form. These observations suggest that relationships between connective tissue, shear force and sensory evaluations are reasonably general for sliced and cubed restructured beef steaks, provided that the raw material is not flaked so finely that connective tissue becomes imperceptible. In general, as the hydroxyproline content increased 1 μg/mg above the background peri/endomysial level, the sensory connective tissue score decreased about 1 unit on the 10 unit scale. Processors can therefore use these relationships as a guide to establishing meaningful quality assurance values for their particular product using either hydroxyproline determinations or multiple-blade shear values.

TABLE 2.

PROPERTIES OF RESTRUCTURED STEAKS MADE WITH EPIMYSIUM AND GRISTLE

	Control	ICT	Epimysium	$S_{\bar{x}}$
Composition				
% Protein	18.8	18.4	18.7	
% Fat	8.7	12.2	10.2	
% Water	70.7	67.1	68.9	
Sarcomere Length (μ)	1.9	–	–	
pH	6.0	6.1	6.0	
Shear Force				
(N/g)	40^{a}	56^{b}	77^{c}	2.7
Collagen	0.91^{a}	3.30^{b}	4.18^{c}	0.07
(μg Hyp/mg)				
Sensory Panel				
Initial Tenderness	7.7^{ab}	7.9^{b}	6.8^{a}	0.35
Connective Tissue	7.6^{b}	5.9^{a}	4.8^{a}	0.46
Overall Texture	7.3^{b}	6.2^{ab}	5.4^{a}	0.41

Values in a row with the same superscript are not significantly different ($P > 0.05$)
$S_{\bar{x}}$ Standard error of the treatment means
Sensory Scores as in Table 1

TABLE 3.

RELATIONSHIPS BETWEEN PROPERTIES OF RESTRUCTURED STEAKS

	Correlation Coefficients			
	Initial Tend.	Connect. Tiss.	Overall Text.	Hydroxyproline
Hydroxyproline	-.40	$-.76^{*}$	-.64	
Shear Force	-.48	-.66	-.54	$.93^{**}$

N = 6
*$P < 0.05$
**$P < 0.01$

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REFERENCES

AOAC. 1984. *Official Methods for Analysis,* 14th Ed. Assoc. of Official Analytical Chemists, Washington, D.C.

BERRY, B.W., SMITH, J.J, SECRIST, J.L. and DOUGLAS, L.A. 1988. Consumer response to restructured beef steaks processed to have varying levels of connective tissue. J. Food Qual. *11*, 15–25.

BERRY, B.W., SMITH, J.J. and SECRIST, J.L. 1986a. Effects of connective tissue levels on sensory, Instron, cooking and collagen values of restructured beef steaks. J. Food Prot. *49*, 455–460.

BERRY, B.W., SMITH, J.J., SECRIST, J.L. and ELGASIM, E.A. 1986b. Effects of pre-rigor pressurization, method of restructuring, and salt level of characteristics of restructured beef steaks. J. Food Sci. *51*, 781–785.

BOOREN, A.M., MANDIGO, R.W., OLSON, D.G. and JONES, K.W. 1981. Effect of muscle type and mixing time on sectioned and formed beef steaks. J. Food Sci. *46*, 1665–1668, 1672.

COSTELLO, W.J., SEIDEMAN, S.C., MICHELS, J.D. and QUENZER, N.M. 1981. Effect of comminution method and pressure on restructured beef steaks. J. Food Prot. *44*, 425–429.

CROSS, H.R., CARPENTER, Z.L. and SMITH, G.C. 1973. Effects of intramuscular collagen and elastin on bovine muscle tenderness. J. Food Sci. *38*, 998–1003.

CROSS, H.R., MOEN, R. and STANFIELD, M.S. 1978. Training and testing of judges for sensory analysis of meat quality. Food Technol. *32*(7), 48–52, 54.

McKEITH, F.K., De VOL, D.L., MILES, R.S., BECHTEL, P.J. and CARR, T.R. 1985. Chemical and sensory properties of thirteen major beef muscles. J. Food Sci. *50*, 869–872.

NOBLE, B.J., SEIDEMAN, S.C., QUENZER, N.M. and COSTELLO, W.J. 1985. The effect of slice thickness and mixing time on the palatability and cooking characteristics of restructured beef steaks. J. Food Qual. *7*, 201–208.

PATERSON, B.C. and PARRISH, F.C., JR. 1986. A sensory panel and chemical analysis of certain beef chuck muscles. J. Food Sci. *51*, 876–879, 896.

RAMSBOTTOM, J.M. and STRANDINE, E.J. 1948. Comparative tenderness and identification of muscles in wholesale beef cuts. Food Res. *13*, 315–330.

RECIO, H.A., SAVELL, J.W., LEU, R., CROSS, H.R. and SMITH, G.C. 1986. Effect of degree of connective tissue removal on raw material yield, chemical and sensory characteristics of restructured beef steaks. J. Food Sci. *51*, 1173–1175.

RUDDICK, J.E. and RICHARDS, J.F. 1975. Comparison of sarcomere length measurement of cooked chicken pectoralis muscle by laser diffraction and oil immersion microscopy. J. Food Sci. *40*, 500–501.

SCHWARTZ, W.C. and MANDIGO, R.W. 1976. Effect of salt, sodium tripolyphosphate and storage on restructured pork. J. Food Sci. *41*, 1266–1269.

STEEL, R.G.D. and TORRIE, J.H. 1960. *Principles and Procedures of Statistics.* McGraw-Hill Book Co., New York.

STRANGE, E.D. and WHITING, R.C. 1988. Effect of temperature on collagen extractability and Kramer shear force of restructured beef. J. Food Sci. *53*, 1224–1225, 1233.

STRANGE, E.D. and WHITING, R.C. 1990. Effects of added connective tissues on the sensory and mechanical properties of restructured beef steaks. Meat Science *27*, 61–74.

WILCOX, J.C. and HOFSTAD, M.J. 1970. Method of preparing a reassembled meat product. U.S. Patent 3,497,361.

WOESSNER, J.F., JR. 1961. The determination of hydroxyproline in tissue and protein samples containing small portions of this amino acid. Arch. Biochem. Biophys. *93*, 440–447.