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TENDERNESS OF SELECTED BOVINE MUSCLES

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Tenderness of muscle has been recognized by most meat researchers as an important quality attribute, perhaps having received more attention than any other quality factor. During recent years, considerable attention has been directed toward elucidating the basic factors responsible for tenderness. Presently, most of the efforts toward this endeavor are concentrated in the areas of connective tissues and contractile proteins.

Connective tissues have been implicated for many years as contributing to meat tenderness. While Husaini et al. (1950), Wierbicki et al. (1955) and Ritchey et al. (1963) reported a significant relationship between collagen connective tissues and muscle tenderness, other workers including Herschberger et al. (1951), Carpenter et al. (1963) and McClain et al. (1965) have reported little or no relationship between collagen tissue content and tenderness. Perhaps some of these differences may be partially explained by results obtained recently in studies conducted at Louisiana State University. It has been generally assumed by meat researchers based upon very limited data, Ramsbottom et al. (1945) that muscles within a given carcass follow a rather consistent pattern with regard to tenderness. However, tenderness values for selected muscles from research cattle coming through our laboratory have differed greatly from the assumed pattern of tenderness for muscles sampled.

Evidence of this variation is shown in Table 1 which illustrates average shear values for selected muscles from cattle subjected to varying conditions antemortem.

Table 1 AVERAGE SHEAR VALUES[1]

No. of Animals	Treatment	Muscle LD	SM	TB
		kg.		
	Nutritionally Stressed[2]			
4	Slaughtered initially	13.2	10.1	9.2
2	Slaughtered 2 weeks	12.2	8.7	9.7
4	Slaughtered 4 weeks	16.1	8.7	9.0
4	Slaughtered 6 weeks	10.1	9.2	10.1
2	Curare injected[3]	11.3	8.4	8.2
1	Broken leg[4]	15.4	8.2	8.2
8	Control Angus heifers	9.6	---	---
8	Progesterone treated[5] Angus heifers	12.4	---	---
7	Control crossbred heifers	11.0	---	---
8	Progesterone treated heifers[6]	15.1	---	---

[1]Shear values were an average of 6 reading from three 2.54cm cores cooked to 70°C in 135°C fat and sheared on a Warner-Bratzler Shear 7 days postmortem.

[2]Cattle were fed on rations containing high levels of rice hulls for 60 days, then placed on fattening ration until slaughtered.

[3]Cattle were injected intramuscularly with tubocurare chloride 6mg/45.4kg body weight immediately prior to slaughter.

[4]Cattle suffered a broken leg approximately 1 hour prior to slaughter.

[5]Progesterone was injected for 20 days to synchronize estrus-cattle slaughtered 7 days later.

[6]Progesterone was injected for 16 days to synchronize estrus-cattle slaughtered 30 days later.

These data indicate more variation in tenderness in the LD muscle than in the SM or TB and reveal that the LD muscle may be less tender than the SM or TB muscles.

Additional carcasses were sampled in order to study the relationship between collagen content in raw and cooked muscles to shear values of these muscles. Mean shear values and collagen content are shown in Table 2.

No significant differences in the quantity of alkali-insoluble collagen were found in uncooked muscles between tenderness groups for LD or TB muscles, and only a slight difference ($P < .05$) was observed in the SM muscles. However, there was a significant ($P < .01$) difference in alkali-insoluble collagen content between muscles within tenderness groups. The less tender LD muscles averaged 15kg in shear value and contained 2.2% alkali-insoluble collagen, while the tender LD muscles averaged 8.3kg in shear value and had 2.5% alkali-insoluble collagen.

Small differences in shear values were observed in the other muscles; yet large differences were evident in the content of alkali-insoluble collagen.

The quantity of residual collagen in muscles after cooking did not differ statistically between muscles studied or between tenderness groups. Regardless of the initial collagen content, muscles tended to reach a relatively constant collagen content upon cooking as shown in Table 2. Obviously some other factor or factors were responsible for tenderness differences in these cattle. Further work is in progress regarding the state rather than quantity of connective tissue in muscles as related to tenderness. Muscles of extreme tenderness differences have demonstrated marked differences in reticular connective tissues. Acid and salt soluble fractions of collagen are being explored also.

Efforts have been directed toward studying the relationship of the state of contractile proteins and muscle tenderness. Locker (1960) observed that relaxed muscles were more tender than partially contracted muscles 2 days postmortem. Partmann (1963) impeded postmortem contraction in strips of a diaphragm muscle by utilizing weights on muscles during aging. Weighted muscles were more tender than unweighted controls. Marsh and Leet (1966) demonstrated that degree of contraction was significantly related to tenderness values. Shortening up to 20% of the original length of the exercised muscle had little influence on tenderness. Toughness increased rapidly with further shortening up to 40% of the original length, yet beyond this point of shortening, the meat became progressively more tender and approached the tenderness value of the meat in which less than 20% shortening had occurred.

Studies in our laboratory have been conducted in order to evaluate the relationship between maximum contraction during rigor in bovine muscles and tenderness and the association of final (7 day) state of contraction and tenderness. Carcasses from 4 bulls, 4 heifers and 4 steers were used. In order to create different contraction patterns between the two sides of each carcass, different initial holding temperatures were employed. Immediately after dressing, the right side of each carcass was subjected

Table 2. MEAN SHEAR VALUES AND ALKALI-INSOLUBLE COLLAGEN IN COOKED AND UNCOOKED BEEF MUSCLE

Tenderness group	N	Longissimus dorsi			Semimembranosus			Triceps brachii		
		Shear value[b]	Alkali-insoluble collagen[a]		Shear value[b]	Alkali-insoluble collagen[a]		Shear value[b]	Alkali-insoluble collagen[a]	
			Uncooked	Cooked		Uncooked	Cooked		Uncooked	Cooked
Less tender	14	15.00	2.20	0.51	9.18	3.14	0.67[c]	9.64	4.98	0.97[c]
S. E.		0.97	0.31	0.18	0.42	0.12	0.09	0.39	0.90	0.23
Tender	14	8.37	2.50	0.28	8.48	3.65	0.56[d]	8.34	5.20	0.80[d]
S. E.		0.49	0.25	0.07	0.36	0.21	0.12	0.35	0.39	0.20

[a]Collagen protein expressed as a percent of total protein.

[b]Kilograms of shear force on a 2.5-cm. core.

[c]N=7.

[d]N=6.

to 1-2°C for rapid chilling the left side was left at 20°C for 9 hours and then transferred to the same temperature conditions as the other side (1-2°C). After 48 hours both sides were transferred to a holding cooler and maintained at 2-3°C for an additional 5 days. Samples were removed from LD and SM muscles for shear value determinations and histological examination at selected intervals for 7 days. Histological samples were frozen immediately upon removal in OCT compound. Frozen tissue blocks were sectioned on a cryostat microtome and sections were collected onto slides treated with EDTA to prevent thaw contraction. Slides were observed with a phase-contrast microscope and sarcomeres were measured with a filar micrometer. Five muscle fibers were selected at random from each section and 5 consecutive sarcomeres were measured in each fiber. The average of 25 readings was used as sarcomere length of each muscle at any given time.

Average sarcomere lengths of LD and SM muscles during maximum contraction are shown in Table 3.

Table 3. Average sarcomere lengths of longissimus dorsi and semimembranosus muscles during maximum contraction.

	Longissimus dorsi		Semimembranosus	
	1 - 2°C	20°C	1 - 2°C	20°C
Bulls	1.34μ	1.52μ	1.70μ	1.67μ
Heifers	1.55	1.45	1.68	1.51
Steers	1.54	1.54	1.60	1.55
Av.	1.50	1.48	1.66	1.57
	1.49		1.62	

SM muscles did not reach the state of contraction of that observed in the LD muscles during rigor. The SM muscles contracted to an average of 78.4% of pre-rigor values while the LD muscles were contracted to 73.7%. Correlation coefficients indicated only a slight relationship between state of contraction at maximum rigor and 7 day shear values. Final state of contraction appeared to be closely associated with tenderness. After 7 days aging, the more contracted LD muscles, between the two temperature treatments, were significantly ($P < .05$) less tender than less contracted LD muscles. Therefore the degree of contraction of muscles after 7 days aging in the carcass may be a significant factor influencing muscle tenderness, particularly in muscles such as the LD where contraction occurs rather uninhibited.

SUMMARY

Tenderness variation between muscles from the same carcass differed greatly and did not conform to generally accepted patterns of tenderness for these muscles. LD muscles differed in shear values more than SM, TB and ST muscles from the same carcass. Alkali insoluble collagen content did not appear to be a major factor in tenderness values of the above muscles. These muscles differed greatly in alkali-insoluble collagen content in the uncooked state but were very similar in collagen content in the cooked state. State of muscle contraction during maximum rigor was not highly associated with muscle tenderness, however, final state of contraction (7 days) was significantly related to shear value at 7 days, particularly in LD muscles where contraction was rather uninhibited.

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