

The Effect of Age, Stretchtension During Thaw Rigor and Heat on Selected Quality Characteristics of Beef Sternomandibularis Muscles

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SUMMARY

Some aspects of the phenomenon of thaw rigor have been studied in order to understand how it affects skeletal muscle as a food. Specifically, studies were conducted to evaluate the tenderness and other quality characteristics of muscle strips retained at rest length or stretched by 50 percent during thaw rigor, and to see whether any observed differences were related to the age or sex of the animals. No statistically significant differences due to the stretched state, age or sex were noted in the 24 hr. post thawing pH or water holding capacity as determined by the Carver Press method, although in the latter parameter, individual animals differed significantly ($P < 0.05$) from one another. Differences in the stretched state affected the cooking loss, cooking contraction, shear values, sarcomere length and fiber diameter. Variations in the cooking loss, cooking contraction and sarcomere length were not significant when considered on between group basis while significant variations were observed in the shear values ($P < 0.05$) and fiber diameters ($P < 0.01$). Significant differences in the response of individual animals within the different groups were noted in the cooking loss, cooking contraction ($P < 0.01$) and shear values ($P < 0.05$). Within group differences were not observed in the estimates of sarcomere length and fiber diameter. Significant differences were not noted in the total collagen, alkali-soluble collagen, and elastin contents of the cow, steer and heifer groups. However, the collagen content of the veal group was significantly greater ($P < 0.005$) and was more readily soluble in dilute alkali than the three other groups. No significant differences in the collagen content or solubility was attributable to the stretched state. Heating of the muscle strips significantly affected collagen solubility ($P < 0.005$) in all the different groups.

INTRODUCTION

DEATHERAGE (1963) characterised meat tenderness or toughness as a quality representing the summation of properties

of the various protein structures of skeletal muscles particularly the myofibrillar and connective tissue proteins. This sensory attribute is further subject to the influence of other quality traits such as the muscle ultimate pH, muscle contractile state as reflected in the sarcomere length and fiber diameter, water-holding capacity of the muscle proteins, and the quantity, age and solubility of the muscle collagen.

Recent work by Abban (1973) showed that the low difference in the ultimate pH of stretched and unstretched muscle resulted in negligible effect on their water holding capacity. Herring, Cassens, Suess, Brungardt and Briskey (1967) reported that stretched muscles are more tender, have longer sarcomeres and smaller fiber diameter than unstretched muscles. They further indicated that the age of the animals caused significant increases in the shear force of the meat possibly due to the higher percent perimysium in the older animals. Wilson, Bray and Phillip (1954) estimated that veal contained significantly greater amounts of collagen than older animals although Hiner, Anderson and Fellers (1954) had earlier reported no such conclusive difference. The increased toughness in meat from older animals therefore appears to be connected with a decrease in collagen solubility with age. All these meat quality attributes were

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observed in meat after normal rigor. Current reports (Marsh and Thompson, 1958; Scopes and Newbold, 1968; Okubanjo, Stouffer, Bensadoun and Sack, 1975) now suggest that under the peculiar conditions of thaw rigor, the muscles undergo drastic physical and biochemical changes which may modify the general meat quality factors. This study was therefore designed to evaluate the influence of stretch tension during thaw rigor on meat tenderness and other attributes of beef sternomandibularis muscle from animals of different ages.

EXPERIMENTAL METHODS

Bovine sternomandibularis muscles were obtained immediately after death from four bovine classes and freed of fat and other adhering connective tissue. All the animals used were of the A maturity grade except for the cows which were of E maturity grade. Each muscle was split along the midline parallel to the fiber direction. One half was restrained at rest length astride a steel frame. The other was stretched by 50 % and similarly restrained. The frames with their attachments were transferred into a -29°C sharp freezer. All operations were completed within thirty minutes of the death of the animals. After freezing, individual strips were wrapped in aluminium foil to prevent surface freezer burn.

Thawing and cooking method

After an approximately 24-hour freezing period, the stretched (T) and control (C) muscle strips were thawed while still restrained at 3°C for another 24 hours. At this temperature both glycolytic and other changes are comparatively slow such the physical manifestations of thaw rigor are not necessarily maximised. A 10cm section was removed from each strip,

rapidly weighed and inserted into a cylindrical stainless steel wire mesh mold. The mold was inserted into a cryovac bag, vacuumized completely, sealed and heated for 30 minutes in water maintained at 85°C .

Estimation of ultimate pH

The measurement of pH was made directly on uncooked samples with a Sargent (Model PBL) pH meter equipped with a combined probe-type electrode.

Physical and Objective Measurements

Each cooked sample was cooled for at least one hour at 3°C , dried on a paper towel and weighed to determine cooking loss. The cooked length was measured to determine relative shrinkage. Three small sections each at least 1.6 cm were cut from each cooked strip. A 1.3 cm diameter core was taken from each section such that the fibers run from one end of the core to the other and sheared three times across the fiber direction using a Warner-Bratzler shear press. Water holding capacity (WHC) of the cooked sample was determined following the procedure of Miller and Harrison (1965). Sarcomere length and fiber diameter were determined as described by Okubanjo *et al.* (1975).

Estimation of intramuscular collagen and elastin

Both cooked and uncooked samples representative of the two experimental treatments were freeze dried, powdered with dry ice in a high speed blender, defatted over a 72-hour period and analysed for soluble and insoluble collagen and elastin. The procedure of Kao and McGavack (1959) was followed in the extraction of the alkali-soluble collagen fraction. The insoluble collagen fraction was isolated following the procedure of Fitch, Harkness and Harkness (1955).

The remaining residue was assumed to be predominantly elastin. Both collagen fractions and elastin residue were analysed for hydroxyproline following the procedure of Woessner (1961) as modified by McClain, Mullins, Hansard, Fox and Boulware (1965). Estimates of collagen and elastin were derived by multiplying the respective hydroxyproline contents by factors of 7.25 (Goll, Bray and Hoekstra, 1963) and 62.5 (Lawrie, 1966).

RESULTS AND DISCUSSION

As a result of the small sizes of calf sternomandibularis muscles the data collected on this group were limited to estimates of the collagen and elastin con-

tents only. Data presented in Table 1 show the effect of maintaining pre-rigor frozen bovine muscle strips in a 50 % stretched state during thaw rigor on their subsequent quality traits. No statistically significant differences due to the stretched state were observed in the 24 hour post-thawing pH among the three classes of animals or among animals within each class. The values were slightly higher than the previously mentioned ultimate pH of 5.4 to 5.7 for this muscle (Marsh, Woodhams and Leet, 1966), suggesting that after the initial drastic decline in muscle pH during thaw rigor development subsequent changes were similar to those of normal rigor in that the ultimate pH was reached later than 24 hours.

TABLE 1

The effect of stretch-tension during thaw rigor on the 24 hour pH, cooking loss, cooking contraction and Water-holding capacity (WHC) of bovine muscles

Class	Raw 24 hour pH		Percent Cooking loss		Percent Cooking Contraction		WHC	
	C	T	C	T	C	T	C	T
Steer	5.91 ^a (0.12) ^b	5.84 (0.06)	31.12 (4.37)	27.68 (5.07)	30.70 (4.70)	42.28 (6.49)	0.75 (0.06)	0.76 (0.04)
Heifer	5.78 (0.10)	5.78 (0.09)	32.32 (2.91)	30.21 (4.75)	34.96 (7.83)	42.97 (8.28)	0.72 (0.04)	0.71 (0.06)
Cow	5.77 (0.06)	5.80 (0.08)	33.49 (2.68)	29.32 (3.81)	42.67 (6.02)	46.50 (5.96)	0.71 (0.05)	0.70 (0.05)

^a Mean of six animals per class

^b Standard deviation from the means.

The imposition of stretch tension during thaw rigor induced a significant decrease ($P < 0.005$) on subsequent cooking loss in the stretched muscle compared with the unstretched control. Individual animals also showed significant variation ($P < 0.01$) in the amount of cooking loss. There were, however, no basic differences when the animals were compared by class. The slightly higher cooking loss observed in the unstretched control suggests that the myofibrillar proteins were rendered

slightly more hydrophobic than similar proteins in the stretched strips possibly due to a higher degree of syneresis during thaw rigor in the unstretched muscle strips.

A significantly higher degree of contraction ($P < 0.005$) was observed in the stretched strips than in the unstretched strips after cooking. Further, individual animals within each class exhibited significant variations ($P < 0.01$) which appeared to be independent of the different animal classes. The interaction between the

treatment and animal classes was fairly significant ($P < 0.05$) indicating a differential response among the three classes. No specific effects on the water-holding capacity of the different classes of animals were noted although individual animals within each class differed significantly ($P < 0.05$) from one another.

The mean values for the Warner Bratzler shear scores, raw sarcomere lengths and fiber diameter are presented in Table 2. Stretching of the muscle strips by 50 %

during thaw rigor induced a significant increase in toughness ($P < 0.05$) as reflected in the shear scores in all the three animal classes. Significant variations were also noted among and within classes ($P < 0.05$) with the cow class showing the greatest degree of toughness both in the stretched and unstretched samples. The corresponding samples from the steer class exhibited the least toughness. The age-related toughness may be attributed to a higher content of connective tissue.

TABLE 2

The effect of stretch-tension during thaw rigor on mean shear values, sarcomere length and fiber diameter of bovine muscle

Class	Shear Values (kg)		Sarcomere length (μ)		Fiber diameter (μ)	
	C	T	C	T	C	T
Steer	5.55 ^a (0.74) ^b	6.11 (0.56)	2.1 (0.18)	3.89 (0.14)	46.47 (4.17)	29.71 (2.23)
Heifer	6.28 (1.53)	6.88 (0.82)	2.01 (0.22)	3.92 (0.16)	46.65 (3.48)	25.48 (2.86)
Cow	8.85 (1.89)	9.58 (2.11)	1.97 (0.16)	3.8 (0.12)	51.97 (2.95)	33.40 (4.03)

^a Mean of six animals per class

^b Standard deviation from the means

The application of stretch tension significantly increased the estimate of sarcomere lengths ($P < 0.005$) while decreasing the fiber diameter ($P < 0.005$) in the three sex classes. For each treatment class the mean sarcomere lengths for these sexes were similar. However, fiber diameter estimates were only similar in the steer and heifer classes. The fibers of the cow class were significantly larger ($P < 0.01$) than those of the steer or heifer class. Previous finding by Tuma, Venable, Wuthier and Henrickson (1962) indicated that muscle fiber diameters generally increase with an advancement in animal age and may be due to a higher content of myofibrillar proteins per unit volume

in the more mature animals. The observed inverse relationship between sarcomere length and fiber diameter is consistent with a previous observation by Herring *et al.* (1967), who showed that longer fibers possess lower fiber diameters.

Data presented in Table 3 and 4 indicate that the solubility of intramuscular collagen decreased with increase in the relative maturity of animals. The veal class had significantly more alkali-soluble collagen ($P < 0.005$) than the steer, heifer or cow class. The decrease in solubility with age was probably due to the formation of more permanent cross-linkages in the older collagen molecules. Further, the veal group contained significantly higher total

TABLE 3

Alkali-soluble collagen content of stretched and unstretched bovine sternomandibularis muscle after thaw rigor

Class	Uncooked		Cooked	
	Unstretched	Stretched	Unstretched	Stretched
Veal	0.88a (0.13) ^b	0.94 (0.15)	1.91 (0.21)	2.26 (0.27)
Steer	0.54 (0.15)	0.62 (0.13)	1.27 (0.24)	1.32 (0.36)
Heifer	0.55 (0.17)	0.53 (0.14)	1.63 (0.44)	1.52 (0.34)
Cow	0.45 (0.08)	0.46 (0.09)	1.34 (0.22)	1.31 (0.38)

^a Mean of observations from six animals per group expressed in gm/100 gm dry defatted tissue.

^b Standard deviation from the mean.

TABLE 4

Total collagen content of stretched and unstretched bovine sternomandibularis muscle after thaw rigor

Class	Uncooked		Cooked	
	Unstretched	Stretched	Unstretched	Stretched
Veal	6.67a (0.79) ^b	6.86 (0.94)	5.45 (0.54)	5.67 (0.70)
Steer	5.40 (0.88)	5.21 (0.71)	4.64 (0.66)	4.56 (0.79)
Heifer	5.56 (0.76)	5.80 (0.99)	4.86 (0.9)	4.75 (0.80)
Cow	5.95 (0.93)	5.81 (0.77)	5.48 (0.81)	5.57 (0.85)

^a Mean of observations from six animals per group expressed in gm/100 gm dry defatted tissue.

^b Standard deviation from the mean.

collagen contents ($P < 0.005$) than the steer, heifer or cow class in agreement with similar findings by Cormier, Wellington and Sherbon (1971). This may be due to the fact that veal contains a lower myofibrillar protein content than the more mature animals. No significant difference was detected in the latter three classes although the cow class contained more collagen as earlier observed by Wilson, Bray and Phillips (1954). Variance analysis indicates that the imposition of stretch

tension during thaw rigor had no significant effect on the collagen solubility or on the total collagen content of the four classes of animals. However, the effect of heat on collagen solubility was highly significant ($P < 0.005$) as collagen was converted by heat into the more soluble gelatin. The effect was more significant in the veal class ($P < 0.005$) and least significant in the cow class ($P < 0.05$) indicating that mature collagen molecules are more heat-stable.

TABLE 5

Elastin content of stretched and unstretched bovine sternomandibularis muscle after thaw rigor

Class	Uncooked		Cooked	
	Unstretched	Stretched	Unstretched	Stretched
Veal	1.13 ^a (0.28 ^b)	1.08 (0.37)	1.22 (0.35)	1.19 (0.38)
Steer	0.59 (0.25) ^b	0.63 (0.20)	0.65 (0.23)	0.62 (0.16)
Heifer	0.69 (0.22)	0.64 (0.14)	0.70 (0.24)	0.73 (0.21)
Cow	0.79 (0.31)	0.83 (0.36)	0.87 (0.28)	0.92 (0.38)

^a Mean of observations from six animals per group expressed in gm/100 gms. dry defatted tissue.

^b Standard deviation from the mean.

The highest proportion of elastin was observed in the veal class while the cow class contained only slightly higher elastin than either the steer or heifer class (Table 5). There was no significant effect due to maximal stretching during thaw rigor on the elastin content. On the other hand, cooking significantly ($P < 0.05$) increased the relative elastin content of the four classes of animals. The observed increase may be attributed to the fact that some of the collagen solubilized into gelatin was lost in the cook-out thereby increasing the relative proportion of the heat stable elastin in the cooked tissue.

As shown earlier, the shear force values were significantly and consistently higher in the stretched thaw rigor muscle than in the unstretched counterpart even though stretching did not affect the total collagen content or collagen solubility. Herring *et al.* (1967) have indicated that when muscles are evaluated on a cross-sectional basis, the percentage of perimysium per unit cross sectional area decreased with short sarcomere lengths and increased with long sarcomere lengths. In another work reported elsewhere,

(Okubanjo *et al.*, 1975), histological observations indicated that both the stretched and unstretched samples exhibited gross myofibrillar rupturing in most fibers although this was more drastic in the stretched muscle. Therefore, the higher myofibrillar rupturing and smaller fiber diameter of the stretched muscle may be said to account for a higher perimysial content per unit cross-sectional area of the cores taken from the stretched samples. This may partly explain the higher shear force observed in the stretched thaw rigor muscle in contrast to the results obtained in bovine muscle after normal rigor by Buck and Black (1967). These workers reported that stretched strips of muscle were consistently more tender than the controls as evidenced by lower shear values.

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