TENDERNESS OF DIFFERENT MUSCLES COOKED TO DIFFERENT TEMPERATURES AND ASSESSED BY DIFFERENT METHODS

A.E. Graafhuis*, K.O. Honikel+, C.E. Devine* and B.B. Chrystall*

*Meat Industry Research Institute of New Zealand,(Inc.),Hamilton, New Zealand
+Federal Centre of Meat Research, Kulmbach, Germany

Factors that affect the tenderness of meat include processing conditions, type of muscle, preslaughter stress, animal age and breed. Ultimately the tenderness depends upon the state of the myofibril, the degree of muscle aging, and the amount and type of connective tissue present.

Meat tenderness is usually objectively measured by methods that have been related to taste panel assessment. Studies of Warner-Bratzler shear-force curves have shown that treatments influencing the myofibrillar proteins such as aging and cooking conditions affect mainly initial yield force values, whereas the peak-force values reflect changes related to animal age, muscle type, muscle connective tissue and also cooking methods (Bouton *et al.,* 1981). Cooking conditions affect the connective tissue by denaturing the collagen at the shrinkage temperatures and subsequent hydrolysis, (Seuss and Honikel, 1990).

The MIRINZ tenderometer (MacFarlane and Marer, 1966) and the pneumatic version (Frazerhurst and MacFarlane, 1983) developed for the New Zealand meat industry, are devices giving a shear-force measurement as a cooked sample is compressed between two blunt wedged shaped teeth. The Warner-Bratzler tenderometer draws a flat blade with a triangular hole in which a cooked sample is placed between a pair of fixed plates, giving a shear-force measurement (Bratzler, 1932).

Comparisons of the MIRINZ tenderometer and the Warner-Bratzler tenderometer have shown their shear-force values to be very highly correlated (Bouton and Harris,1972a).

Knowledge of the relationship between different tenderometers and changes induced by different cooking methods, allows tenderometer results to be compared from different laboratories.

For this study two mechanical methods, the Warner-Bratzler shear device (Bratzler, 1932) and the MIRINZ pneumatic tenderometer (Frazerhurst and MacFarlane, 1983), were compared in their original form as individual machines. Results were also obtained using their respective shear heads attached to an Instron 4301 Materials Testing Machine. The second approach provided a direct comparison of the shear mechanism without differences in rates of force application. Samples of five muscles cooked to selected end-point temperatures, were used in the study.

METHODS

Sample Preparation

Cattle slaughtered by a processing plant were held for 24 hours in a chiller so that the deep meat temperature did not fall below 6°C. Temperature profiles of carcasses in the chiller after slaughter and of the samples aged at 10°C, were continuously monitored using Delphi/MIRINZ data loggers (model 861) with a teflon covered probe. Muscles used were the *m. longissimus dorsi, m. psoas major, m. biceps femoris, m. supraspinatus* and *m. sternomandibularis*. Only muscles with an ultimate pH less than 5.70 were used. All muscles except the *sternomandibularis*, were excised 24 h postmortem and five 150 mm x 50 mm x 50 mm longitudinal samples of each were prepared for cooking. The *sternomandibularis* muscle was excised immediately after slaughter and laid out at 15°C to enter rigor with only minimal shortening. The samples to be aged were vacuum packed and held at 10°C for 96 hr (120 h postmortem). All samples were cooked in a waterbath at 100°C to internal meat temperature end-points of 55, 60, 65, 70 and 75°C, as measured by copper/constantan thermocouples. Immediately the samples had reached the end-point cooking temperature, they were chilled on ice and were sheared using the various tenderometer devices, the same day as they were cooked.

Tenderometer Evaluation

The shear-force responses from the MIRINZ tenderometer, the Warner-Bratzler tenderometer and the Instron set up as a MIRINZ or a Warner-Bratzler tenderometer were compared. The maximum shear-force values for the MIRINZ and the Warner-Bratzler tenderometers and the peak shear-force values for the Instron assessment methods, expressed as kilograms force (kgf), were recorded as the mean of ten bites on 10 mm x 10 mm cross-section x 150 mm long samples. Samples were sheared at right angles to the fibre axis. The Instron was set up for both types of head with the crosshead speed set at 60 mm/min. Samples from each muscle were sheared by each device.

RESULTS

The mean shear-force values for unaged *biceps, longissimus, psoas* and the *supraspinatus* muscles were plotted against the cooking end-point temperatures show a maximum shear-force between 60°C and 70°C. For the aged samples there was no significant curvature between 55°C to 75°C. However the 75°C values were slightly higher than the 55°C values. An example of such curves for the *longissimus*, is given in Figure 1. Instron shear-force values for both heads mimicked the results found using the original shear devices (Fig. 2), although at lower end-point temperatures there were marked differences for the MIRINZ shear-heads, the Instron-MIRINZ values at 55°C being 25% lower than the MIRINZ result. Both the Warner-Bratzler and the Instron-Warner-Bratzler results were similar.

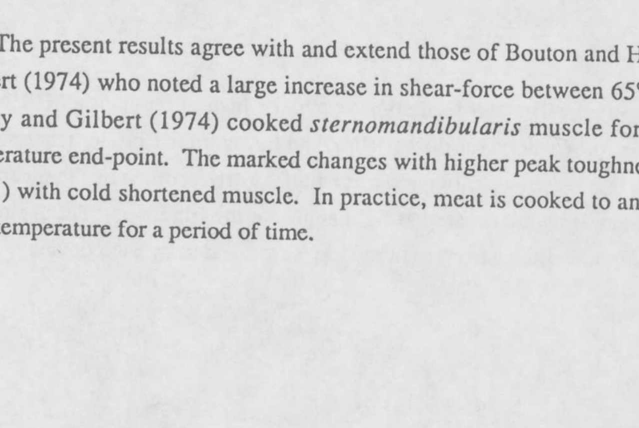
Similar tenderness relationships to those shown for *longissimus* muscle in Figure 1, were obtained for the *biceps, psoas* and *supraspinatus.*

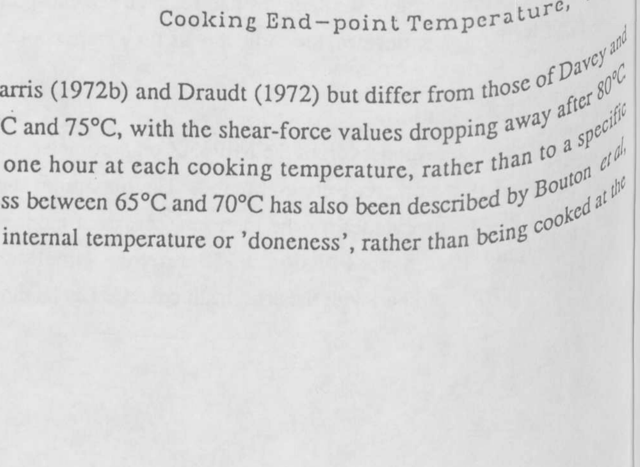
The results for unaged *sternomandibularis* muscle in Figure 3, show curves flatter to those for the other unaged muscles tested. The shear-force values for both the unaged and aged *sternomandibularis* muscle from the Warner-Bratzler tenderometer were approximately 50% higher than for the MIRINZ tenderometer. The relationships between results for all muscles except the *sternomandibularis* on the MIRINZ and Warner-Bratzler tenderometers show a high correlation (Figure 4). The results from the original devices are given in Figure 4(a), and from the Instron based devices are given in Figure 4(b). The regression coefficients for figure 4(a) is, Warner-Bratzler kgf = 0.63 MIRINZ kgf + 0.61 and for figure 4 (b) is, Instron Warner-Bratzler kgf = 0.72 Instron MIRINZ kgf + 0.60. The correlation coefficients are 0.91 and 0.92 respectively. The regression equations from the data in Figure 4a can be used to convert *longissimus* shear-force values from one machine to another.

DISCUSSION

The high correlation of the tenderness values measured using the MIRINZ and Warner-Bratzler tenderometers and their respective Instron modifications for all muscles, except the *sternomandibularis*, indicates that these instruments can be used confidently for comparative tenderness assessments, when identical samples are used. Different sample shapes and sizes are likely to modify the relationships. Changes to the Warner-Bratzler blade will also influence results.

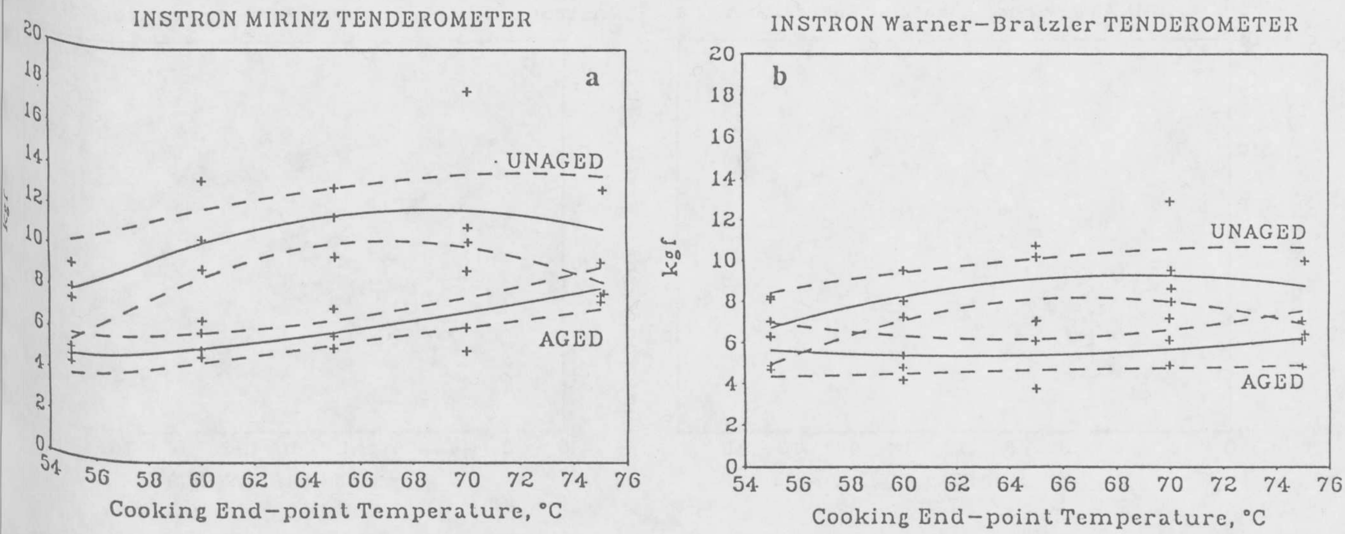
Figure 1. *Longissimus* shear-force values plotted against end-point temperatures between 55° and 75°C for(a) unaged and aged muscle, MIRINZ tenderometer, and (b), unaged and aged muscle, Warner-Bratzler tenderometer. The curves shown here were plotted using a quadratic, with the 90% confidence limits shown by the broken lines.





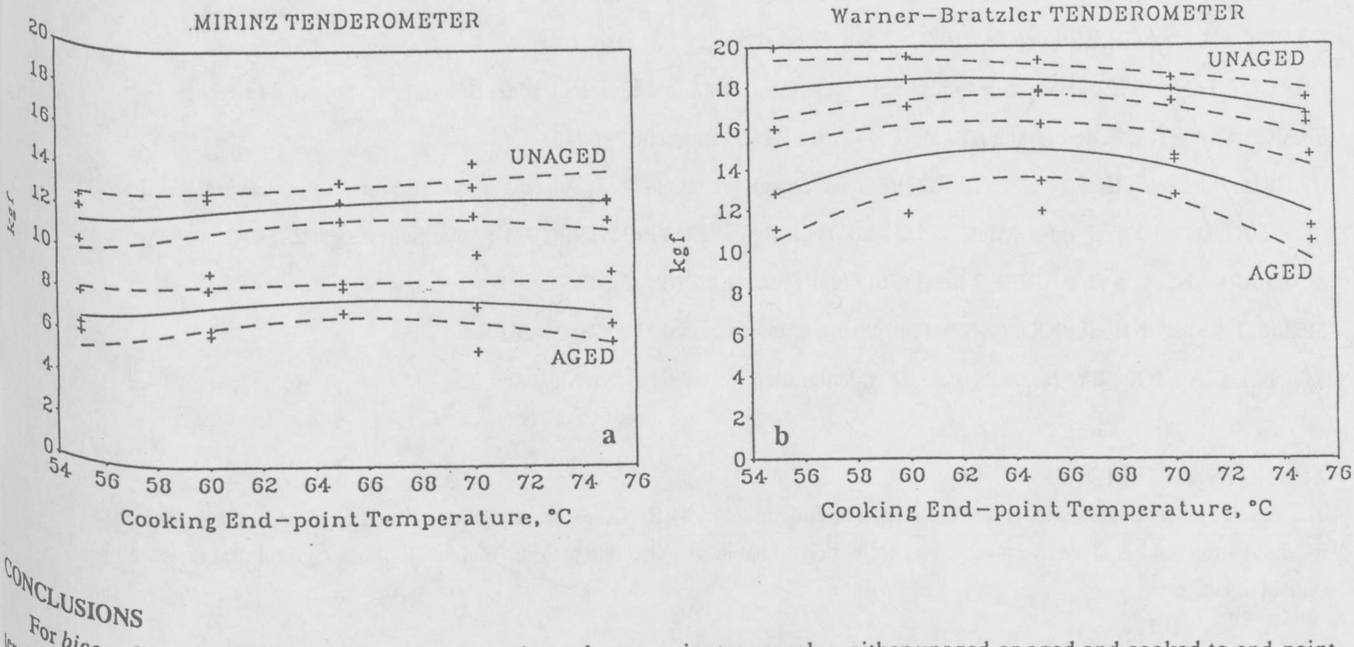
The present results agree with and extend those of Bouton and Harris (1972b) and Draudt (1972) but differ from those of Davey and Gilbert (1974) who noted a large increase in shear-force between 65°C and 75°C, with the shear-force values dropping away after 80°C. Davey and Gilbert (1974) cooked *sternomandibularis* muscle for one hour at each cooking temperature, rather than to a specific temperature end-point. The marked changes with higher peak toughness between 65°C and 70°C has also been described by Bouton *et al.* (1981) with cold shortened muscle. In practice, meat is cooked to an internal temperature or 'doneness', rather than being cooked at the final temperature for a period of time.

Figure 2. *Longissimus* shear-force values plotted against end-point temperatures between 55° and 75°C obtained using the Instron using both MIRINZ and Warner-Bratzler shear heads, for(a) unaged and aged muscle, MIRINZ Instron tenderometer and (b), unaged and aged muscle, Warner-Bratzler Instron tenderometer. The curves shown were plotted using a quadratic with the 90% confidence limits shown by the broken lines.



The increase in shear-force occurring between 60°C to 70°C, as shown by the unaged treatment, possibly results from an interaction of the initial changes in collagen temperature stability occurring over the temperature range 60°C to 65°C (Horgan *et al.*, 1991) followed by increases in actomyosin rigidity at temperatures greater than 65°C, (Young, *et al.*, submitted for publication). The interaction between myofibrillar and collagenous proteins over the temperature range being considered, is complicated with both longitudinal and transverse collagen shrinkage occurring, (Seuss and Honikel, 1990).

Figure 3. Shear-force values for the *sternomandibularis* plotted against end-point temperatures between 55°C and 75°C using the MIRINZ (a) and the Warner-Bratzler tenderometer (b), for unaged and aged muscles. The curves shown were plotted using a quadratic with the 90% confidence limits shown by the broken lines.

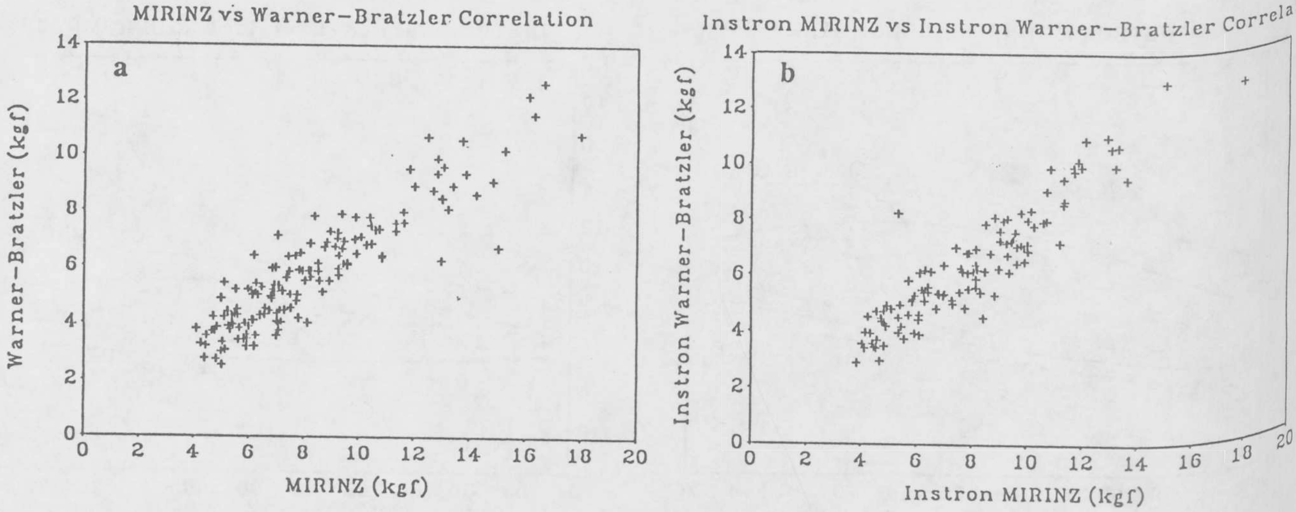


CONCLUSIONS

For *biceps femoris, longissimus dorsi, psoas major* and *supraspinatus* muscles, either unaged or aged and cooked to end-point temperatures between 55°C and 75°C, MIRINZ tenderometer and Warner-Bratzler shear device readings are highly correlated. MIRINZ tenderometer can be converted to Warner-Bratzler shear-force values, and vice versa, by applying the appropriate regression equations.

The maximum shear-force occuring for unaged treatments between 60°C and 70°C, suggests that there is a complex interaction with collagen and myofibrillar proteins. For the aged samples of the same muscles, there was no significant curvature between 55°C and 75°C.

Figure 4. MIRINZ and Warner-Bratzler tenderometer values plotted against each other for all muscles, except the *stenomandibularis*, for all cooking end-point temperatures, for unaged and aged treatments. In (a), the original machines were used, and for (b), the Instron using both MIRINZ and Warner-Bratzler shear heads were used.



However, the 75°C values were slightly higher than the 55°C values. The shear-force values for the aged samples over the range were significantly lower than those of the unaged samples. Instron shear-force values for both heads mimicked the results found using the original shear devices, although there was some marked shifts at lower end-point temperatures.

The different relationship between the two tenderometers observed when using the *sternomandibularis* muscle compared to that observed for the other muscles, suggests the *sternomandibularis* is not a good model for comparative tenderness standards.

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