

MECHANICAL CHARACTERISTICS OF SINGLE MUSCLE FIBRES VERSUS GROUPS OF MUSCLE FIBRES FROM RAW AND COOKED PORCINE LONGISSIMUS MUSCLE

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Background.

The relative contributions to toughness of various structural units in meat (e.g. muscle fibres) are becoming more documented. For example, the breaking extension of single muscle fibres of raw porcine longissimus muscle (Mutungi et al., 1995; Willems and Purslow, *in press*, Willems and Purslow, submitted) was notably lower than as reported for raw meat samples (e.g. Stanley et al., 1971). Thus, as pointed out by Purslow (1994), the mechanical properties of meat samples seem to have contributions from interactions between the various structural units. To examine specifically the potential contribution from interactions between adjacent muscle fibres (e.g. by shear connections through the endomysium, as discussed by Purslow and Trotter 1994) separately from any contributions that arise from interactions between muscle fibre bundles, tensile tests on groups of muscle fibres free of perimysium are required.

Objectives.

To examine the role of endomysial shear connections during extension to complete fracture of groups of muscle fibres of raw and cooked porcine longissimus muscle.

Methods.

A sample of the longissimus muscle of a gilt pig was excised 1 hour postmortem, dissected into small samples, vacuum packed, allowed to enter rigor at 22°C for 12 hours and then frozen (-26°C). A thawed raw muscle sample was divided and one piece vacuum packed and heated for 1 hour at 80°C. Single muscle fibres (n = 15) and groups of muscle fibres (n = 15) were isolated from raw and cooked samples and mounted in a mechanical testing device attached to the stage of Leitz Laborlux S stereomicroscope with dual 35 mm camera and video systems (Mutungi et al., 1995). The diameter and length and of the unextended fibres and groups of fibres were measured. Muscle fibres and groups of muscle fibres (raw and cooked groups contained 13-51 and 9-42 muscle fibres, respectively) were extended at a strain rate of approximately 9% per min until complete fracture occurred. The observed strain is given as an increase in muscle sample length divided by the initial length and expressed as percent. Force values were converted to stress by using the cross-sectional area of the unextended muscle fibre or groups of muscle fibres. Results of our study will be given as mean ± s.e.. Analysis of variables were performed using student tests (P < .05).

Results and discussion

Raw meat. Typical stress-strain curves for a raw single muscle fibre and a group of raw muscle fibres show apparent shape differences, as exemplified by substantially steeper gradients in raw muscle fibres at relatively low strains. The initial high gradients in both curves are followed by a gradually decreasing gradient in stress until maximum stress (visualised in inset for single muscle fibres by different scaling of the x-axis). In groups of muscle fibres, maximum stress ($1.46 \pm 0.15 \text{ kg}\cdot\text{cm}^{-2}$) and strain at maximum stress ($59.05 \pm 9.32 \%$) was 65% lower and 89% higher, respectively, than of their constituent muscle fibres ($4.22 \pm 0.03 \text{ kg}\cdot\text{cm}^{-2}$ and $6.61 \pm 1.35 \%$). Dissection might have damaged or weakened the endomysial connective tissue sheet still enveloping the muscle fibres, and as such affecting the mechanical properties of such muscle fibres during tensile tests. However, maximum stress values of raw single muscle fibres were significantly higher than for groups of raw muscle fibres, an observation not to be expected if the dissection procedure had serious damaging effects on the single muscle fibres. This observation, however, is not necessarily convincing in itself as it might be suggested that load sharing in groups of muscle fibres could have reduced its maximum stress value. If this would be the case, then it might be expected that the relatively stronger muscle fibres fractured last during progressive rupture of a group of muscle fibres. In our experiments it happened occasionally that extension of groups of muscle fibres resulted in a single remaining muscle fibre at relatively high strain and any effect of load sharing on this remaining muscle fibre can be clearly excluded. For these muscle fibres which fractured last, assuming that they had an average diameter, the maximum stress was $3.21 \pm 0.29 \text{ kg}\cdot\text{cm}^{-2}$. These values appeared even to be lower than the average maximum stress values during tensile tests on raw single muscle fibres. In single muscle fibres, lengthening of sarcomeres in series (i.e. local strain) and slippage of individual myofibrils may contribute to their observed strains. The remarkably high extensibility of groups versus individual raw fibres can be explained on the basis of load sharing neighbouring muscle fibres, which results in more uniform lengthening of sarcomeres in the majority of muscle fibres (Willems and Purslow, submitted).

Cooked meat. Typical stress-strain curves are shown in Figure 2 for a cooked single muscle fibre and a group of cooked muscle fibres. The sigmoid shapes of these curves were very similar, as characterised by steep increases in stress at relatively low strains, followed by a gradual decrease and an increase in stress at relatively higher strains until maximum stress. Note that in groups of muscle fibres the decrease in stress following maximum stress was more or less stepwise, as not all muscle fibres fractured simultaneously. Maximum stress

of single muscle fibres ($10.00 \pm 1.61 \text{ kg}\cdot\text{cm}^{-2}$) and groups of muscle fibres ($8.10 \pm 0.69 \text{ kg}\cdot\text{cm}^{-2}$) were similar and were achieved at similar strains (197.37 ± 11.52 and 186.03 ± 12.22 % for single fibres and groups of fibres, respectively).

Conclusions.

Maximum stress and extensibility (i.e. observed strains) of groups of muscle fibres of raw meat are significantly affected by shear connections between the muscle fibres. In cooked meat there is no strong effect of interactions between adjacent muscle fibres on the fracture behaviour of the group versus fracture of a single muscle fibre.

Literature.

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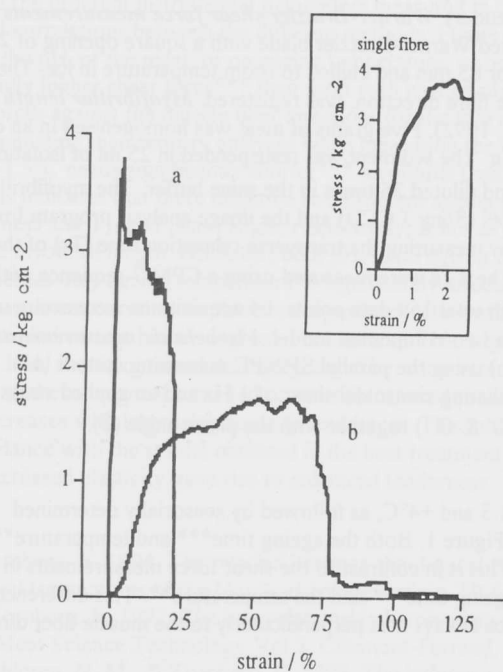


Figure 1. Typical examples of the stress-strain relationships for a single muscle fibre (a) and a group of muscle fibres (b) from 0.5 day-conditioned raw porcine longissimus muscle. Inset shows the stress-strain relationship of the same single fibre with expanded x-axis scaling.

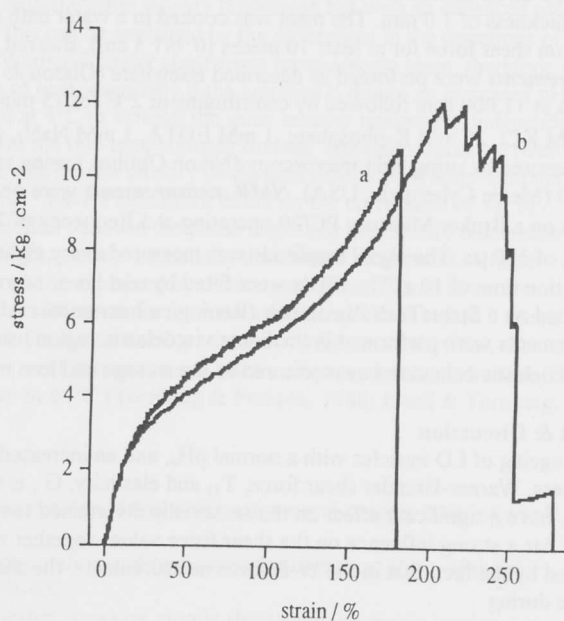


Figure 2. Typical examples of the stress-strain relationships for a single muscle fibre (a) and a group of muscle fibres (b) from 0.5 day-conditioned cooked porcine longissimus muscle.