VISUALIZATION OF *RIGOR MORTIS* DEVELOPMENT IN ATLANTIC SALMON AND *M. LONGISSIMUS DORSI* OF PORCINE AND BOVINE MUSCLES

Øivind Torslett, Anders Kiessling and Erik Slinde, Institute of Marine Research, P.O.Box 1870 Nordnes, N-5817 Bergen, Kjell Ivar Hildrum and Bjørg Narum Nilsen, MATFORSK, Norwegian Food Research Institute, Osloveien 1, N-1430 Ås, Norway. Katja Rosenvold and Anders Karlsson, Danish Institute of Agricultural Sciences, P.O.Box 50, 8830 Tjele, Denmark. Eva Tornberg, Lund University, Department of Food Engineering, P.O. Box 124, 22100 Lund, Sweden.

Key words

Contraction, salmon, beef, pork

Background

The understanding of the *rigor mortis* process, which is both time and temperature dependent, is of vital importance in all animals. During *rigor*, shortening of muscle fibres occurs that can give gaping in fish fillets and reduce tenderness in muscles from land based animals. The lateral contraction occurring during *rigor* is a critical factor for water-holding capacity. The *rigor* process is generally studied using biochemical and biophysical methods on the micro- and macroscopic scale. As glycogen is unevenly distributed between individual fibres, this gives rise to a longer *rigo*r development in a whole muscle compared to a single fibre (Jeacock, 1984). In salmon between 90 to 95% of striated muscle is located in one large swim muscle, that is built up of discrete layers of fibre types, dominated (up to 95%) by type IIB fibres located in the core of the muscle (Bone, 1978). Bovine LD has a fibre composition consisting of 43% white, 23% red, and 34 % intermediate fibres (Olsson *et al*., 1994). The porcine LD consists of 8% type I fibres, 8% type IIA fibres and 84% type IIB fibres (Karlsson *et al*., 1993).

Objective

The purpose of the study has been to visualize and compare the *rigor* development in different parts of muscles from Atlantic salmon (*Salmo salar*), and beef and porcine *m. longissimus dorsi* (LD) by image and photographic aids. This approach is seldom taken in studies on *rigor* development. The muscles used were judged rather homogenous with regard to contraction characteristics.

Materials and methods

One salmon was killed and the fillet was placed on a glass plate 10 min *post mortem* and photographed at an interval of 6 minutes for 24h at 12°C. Contraction and widening were measured directly on the pictures. Hot boned LD's from one electrically stimulated young bull of Norwegian Red were excised approx. 50 min *post mortem* and photographed every 10 min for 48h from 2h *post mortem* at 14°C. One porcine LD was obtained from the slaughterhouse and brought to the laboratory 25 min *post mortem*, placed on a laminated cardboard in a chilling room at 4°C and photographed at an interval of 4 minutes for 24h. The processes of *rigor mortis* in the three species were visualized as a movie. To avoid drying the muscles were brushed with olive oil and/or paraffin.

Results and discussion

The main contraction events in a salmon fillet at the present experimental conditions are shown in Figure 1. The tail region contracts first, followed by a contraction of the whole fillet. The muscle fibres are oriented in the length of the fillet, and as they contract a widening of the total fillet is observed due to the increase in transverse volume. The contraction in the bovine LD muscle is characterized by a contraction of the caudal end as shown in Figure 2. Hardly any contraction was observed in the cranial end. The porcine LD muscle contracts first in the dorsal part of the caudal end, followed by contraction in the ventral caudal end, Figure 3. As observed in the bovine LD, hardly any contraction was observed in the cranial region. Neither widening of the muscle nor any loss of water was observed in the latter two muscles.

We believe that comparative studies on muscle contraction among different species can give fundamental information on how the *rigor* process proceeds. In this connection, fish has the unique property that the body temperature can be modulated pre-slaughter, thereby giving more basic information on the effect of temperature regime on muscle quality. The contraction observed in the salmon fillet clearly show that the contraction of the different regions proceeded at both different time and at different speed. This may partly be explained by difference in temperature gradients, but also by the knowledge that even if the muscle mainly contains type IIB fibres the intra muscular microstructure is further differentiated. The bovine LD muscle showed a time dependent *rigor* development that differs in different parts of the muscle. The variation in *rigor* onset within the muscle was not as outspoken as in salmon. The white fibre content is more abundant on the belly side for *m.semitendinosus* (Totland *et al*., 1988) and therefore it contracts earlier but usually to a lesser extent than the red fibres (Hertzman *et al.*, 1993).

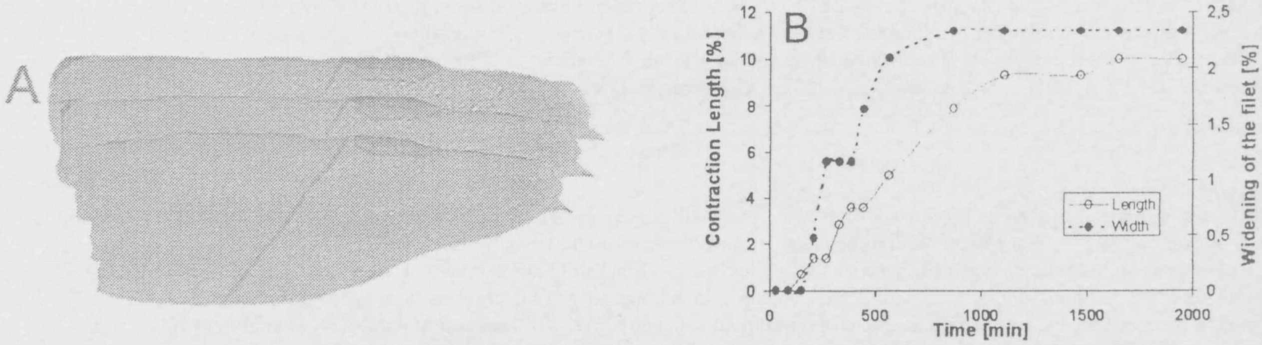

Figure 1. Development of *rigor mortis* in a salmon fillet (start 1.129 kg, end 0.948 kg, giving a drip loss of 16 %). (A) The picture shows the salmon fillet after 0.5 h, 7.5 h and 43 h *post mortem.* (B) Measured contraction and widening of a salmon fillet as a function of time.

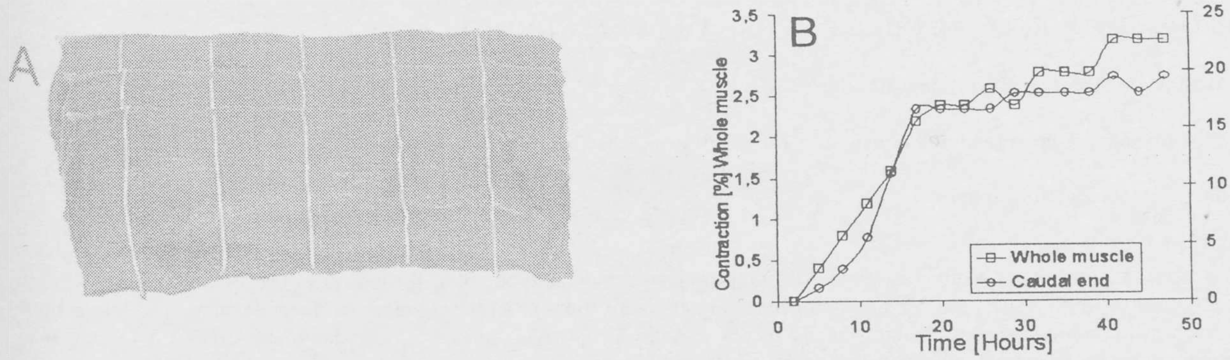

Figure 2. Development of *rigor mortis* in a 52 cm long beef *m. longissimus dorsi* and weighing 2.55 kg. (A) The picture shows the muscle after 2 h, 20 h and 40 h *post mortem*. (B) Measured contraction in the beef *m. longissimus dorsi* as a function of time.

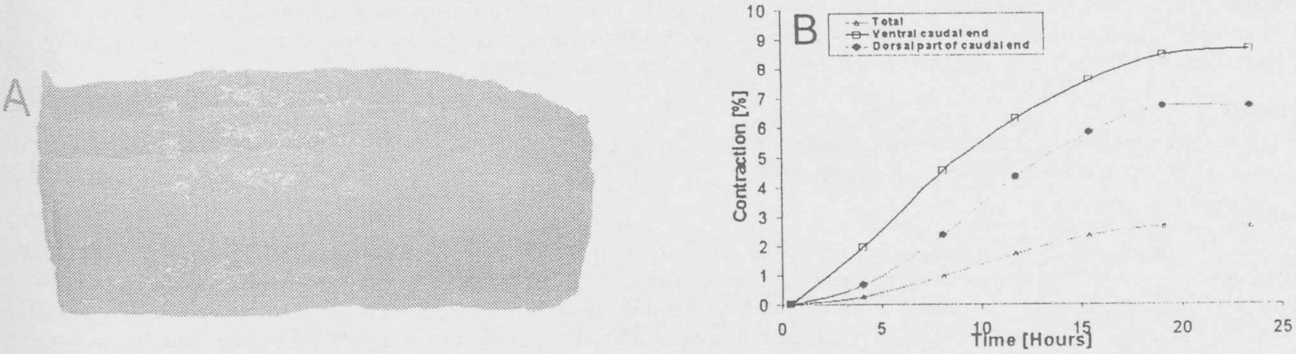

Figure 3. Development of *rigor mortis* in a 39 cm long porcine *m. longissimus dors*i weighing 1.314 kg. (A) The picture shows the muscle after 25 min, 3h 20 min and 24 *post mortem*. (B) Measured contraction in the porcine *m. longissimus dorsi* as a function of time.

The porcine LD muscle contracted in segments, first the dorsal part of the caudal end, then the ventral part of the caudal end follows, whereas hardly any contraction was observed in the cranial region; which is where PSE (pale, soft and exudative) is normally pronounced. Contraction has been shown to correlate to drip loss (Honikel *et al*., 1986) in pork. The differences in contraction pattern observed could be one explanation to differences in drip loss observed along the porcine LD. Whether the cranial end had already contracted 25 min *post mortem* when the filming started, or whether it did not contract at all, is at present unknown. The lack of widening may be explained by vertical instead of horizontal expansion.

From our photographic analysis, variations seen in time dependence of *rigor* development can be explained simply by the fact that the variation in contraction and fibre type is so high within a muscle that it might be difficult to obtain parallel samples. We believe that visual imaging can be a powerful tool in the analysis of the *rigor mortis* development and may add further knowledge to our understanding of the formation of drip loss.

Conclusion

The photographic visualizations of the *rigor mortis* process in three different species (salmon, beef and pork) show large differences in the overall muscle contraction. It is evident that muscle contraction in *rigor mortis* is a segmental process, as different muscle segments contract at different times and to varying degrees. This can be explained by the differences in animal *ante mortem* stress, in muscle fibre types and different characteristics of the same fibre type, in energy/glycogen contents at slaughter or in differences in *post mortem* temperature or temperature gradients in the muscles.

References

Bone, Q. (1978) Locomotor muscle. In: Fish Physiology Ed. Hoar, W.S. and Randall D.J. Vol VII, pp 361-424, Academic Press, New York.

Hertzman, C., Olsson, U. and Tornberg, E. (1993) The influence of high temperature, type of muscle and electrical stimulation on the course of rigor, ageing and tenderness of beef muscles. Meat Science, 35, 119-141.

Jeacocke, R. E. (1984) In Recent advances in the chemistry of meat, ed. A.J. Bailey, Royal Society of Chemistry, London, Sp. Publ. No.47, p.41

Honikel, K.O., Kim, C.J., Hamm, R. and Rocales, P. (1986). Sarcomer shortening of prerigor muscles and its influence on drip loss. Meat Science, 16, 267-282.

Karlsson, A., Enfält, A-C., Essén-Gustavson, B., Lundström, K., Rydhmer L., Stern, S. (1993). Muscle Histochemical and Biochemical Properties in Relation to Meat Quality During Selection for Increased Lean Tissue Growth Rate in Pigs. J. Animal Sci. 71, 930-938.

Olsson, U., Hertzman, C. and Tornberg, E. The influence of low temperature, type of muscle and electrical stimulation on the course of rigor, ageing and tenderness of beef muscles. Meat Science 37, 115-131, 1994.

Totland, G.K., Kryvi, H. and Slinde, E. (1988) Composition of muscle fibre types and connective tissue in bovine *m. semitendinosus* and its relation to tenderness. Meat Sci. 23, 300-315.