Ultrastructure in electrically stimulated dark cutting beef early post mortem

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Introduction

Stressed animals, with a low content of muscle glycogen when slaughtered, develop dark cutting meat. Dark cutting meat is characterized by high ultimate pH, dark colour, swollen muscle fibres, a low content of the break-down products of the glycolysis, high water-binding capacity, short shelf-life, flat flavour and by an improved tenderness (Potthast & Hamm, 1976; Augustini & Fischer, 1979; Gill & Newton, 1979; Fischer & Hamm, 1980; Tarrant & Sherington, 1980). Tenderness of muscle has been shown to be pH dependent in beef (Martin et al., 1971). Dark cutting beef, with a high ultimate pH, is more tender than normal beef with an ultimate pH of about 5.5, whether sensorily or instrumentally evaluated (Bouton et al., 1973).

Several researchers have shown the tenderizing effect of electrical stimulation (reviewed by Cross, 1979; Bendall, 1980) although the exact mechanisms are unknown. A tendency for electrically stimulated dark cutting meat to be more tender than non-stimulated dark cutting meat has been reported (Sorinmade, 1978; Fjelkner-Modig & Rudérus, 1983). Dutson et al. (1982), however, found that electrical stimulation did not influence the tenderness of dark cutting meat when sensorily or instrumentally evaluated 48 hours after slaughter. They suggested that the rapid pH decline normally associated with electrical stimulation was necessary in order to produce an increase in tenderness.

To be able to conclude whether or not electrical stimulation induces structural changes in dark cutting muscles, electron micrographs of non-stimulated and electrically stimulated dark cutting muscles from one carcass were produced at different times *post mortem*. Pronounced ultrastructural changes in the muscle fibres, not reported before, were found to occur at a very early stage during the *post mortem* process in the electrically stimulated part. However, tenderness was not improved by electrical stimulation.

Materials and Methods

The animal was stunned using a captive bolt pistol, exsanguinated and electrically stimulated within 10 minutes of stunning. Stimulation continued for 32 s with a peak voltage of 85V (current flow approximately 0.65A) and the use of square wave pulses of 5 ms duration repeated every 72nd ms. The current was applied through a clip in the nostrils, with the shackle and overhead rail acting as the negative electrode.

M. longissimus dorsi was removed from one side of the carcass immediately before and from the other side immediately after stimulation and the two sides were transported to the laboratory. The muscles were wrapped in polyethylene bags and stored at 22°C for the first three hours, at 10°C for the next 21 hours and at 4°C for the following six days. Samples from the muscles were taken at regular intervals during the first day for transmission electron microscopy and determination of pH. Shear force was determined 7 days after slaughter.

Samples for transmission electron microscopy were prepared according to the procedure described by Fabiansson et al. (1984). At each testing time about 5-13 specimens were examined using phase-contrast microscopy and about 4-7 different blocks were sectioned and examined in the electron microscope.

pH was determined in homogenized samples according to Bendall (1978) and shear force was measured using a Warner-Bratzler shearing device mounted in an Instron Universal Testing Instrument according to Nilsson et al. (1979).

Results and Discussion

The ultimate pH of the dark cutting carcass was 6.65. Electrical stimulation hastened the pH drop slightly, but in relation to the non-stimulated counterpart the difference never exceeded 0.2 pH units (Fig. 1).

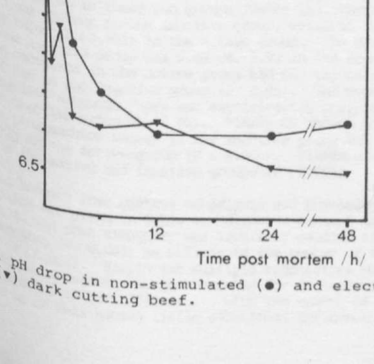

Fig. 1. pH drop in non-stimulated (●) and electrically stimulated (▼) dark cutting beef.

Electron micrographs of muscle samples were produced at 2, 3, 4 and 6 hours after slaughter. The non-stimulated dark cutting samples looked fairly normal at 2, 3 and 4 hours, but some minor irregularities in the Z-discs could be seen. At 6 hours the Z-discs in some muscle fibres were broadened, the I-bands were reduced in width and part of the muscle seemed to be in rigor (Fig. 2). In the electrically stimulated dark cutting samples some fibres showed changes after only 2 hours with less densely occurring thin filaments and disorganized Z-disc material resembling Z-disc streaming (Fig. 3). At 3 hours the variability in-between fibres was great with relatively normal fibres intermingled with fibres showing I-bands reduced in width and broadened Z-discs, much the same as in the non-stimulated samples at 6 hours. At 4 and 6 hours many muscle fibres showed contractions of some sarcomeres and concomitant tearings of neighbouring sarcomeres. There were signs of heavy contractions which resulted in a very dense appearance with a new banding pattern, with condensed material in the Z-disc region and the complete disappearance of the I-band regions. Large parts of complete disorganization were also seen with no identifiable structural components (Figs, 4 and 5). This picture is not seen in normal carcasses even after ageing for 9 days (Gann & Merkel, 1978) or in low voltage electrically stimulated normal carcasses aged for 24 h (Fabiansson & Libelius, 1984).

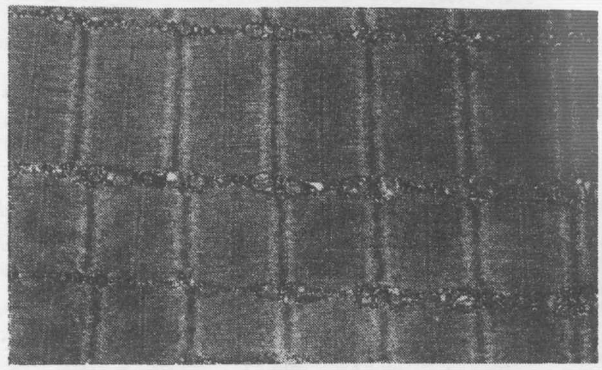

Fig. 2. Unstimulated sample 6 hours post mortem. Note shortening of sarcomeres, slightly broadened Z-discs and reduced width of the I-band. x 11,750.

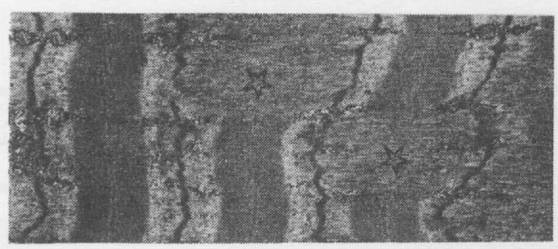

Fig. 3. Electrically stimulated sample 2 hours post mortem. Z-disc streaming is indicated by asterisks. x 11,750.

Fig. 4. Electrically stimulated sample 4 hours post mortem. Pronounced sarcomere shortening and contractures with concomitant tearings of I-band regions (asterisks). x 11,750.

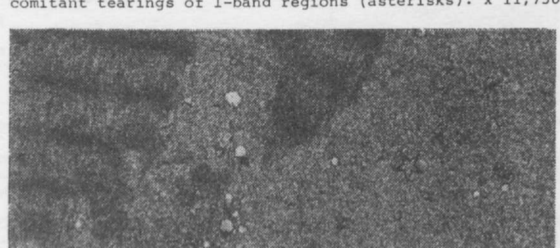

Fig. 5. Electrically stimulated sample 6 hours post mortem. Advanced shortening of sarcomeres with myofibrillar dissolution and loss of myofibrillar continuity replaced by a fine granular material (asterisk). x 11,750.

The shear forces for the non-stimulated and electrically stimulated dark cutting muscles were 2.45 (0.59) kg and 2.70 (0.77) kg respectively (standard deviation within brackets). Shear force values of about 3.30 are usually recorded in non-stressed unstimulated carcasses. Dutson et al. (1982) suggested that in the absence of the rapid pH decline normally associated with electrical stimulation, neither the stimulation itself nor the contractions produced were sufficient to produce the desired effects on palatability. The findings reported here indicate that electrical stimulation has a profound influence on dark cutting meat without a marked pH drop, but it does not produce the increase in tenderness that has been found in non-stressed animals. Since the non-stimulated dark cutting beef is very tender in itself, electrical stimulation is not expected to effect tenderness.

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