Does electrical stimulation increase beef tenderness apart from the prevention of cold shortening ?

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Introduction

It is well known that application of low voltage electric currents to beef carcasses causes an increase in the rate of muscle pH fall and reduces the time for onset of rigor mortis (Shaw and Walker, 1977)(Vandekerckhove et al, 1978 b). Electrical stimulation can be used to prevent "cold shortening" e.g. the intensified contraction brought about by chilling carcasses before onset of rigor mortis and reflected in a decrease in sarcomere length (SL) : onset of rigor is accelerated by electrical stimulation, followed by chilling of the carcasses. When stimulated and non stimulated bull carcasses or carcasse sides are both chilled shortly after slaughtering we observed an increased tenderness in muscles of the stimulated sides or carcasses concomittant with an increased sarcomere length (Vandekerckhove et al, 1978 b). For semitendinosus however, an increase of tenderness was noted although no change in SL was observed. This could indicate an effect of electrical stimulation on beef tenderness quite apart from changes in degree of shortening (cold shortening). Similar increases in beef tenderness after electrical stimulation with no increase in sarcomere length were observed by Smith et al (1977) and Savell et al (1977).
The experiments described in this paper were carried out to confirm the existence of a tenderizing effect of electrical stimulation apart from an effect on degree of shortening.

Materials and Methods

Four Bulls (animals 309, 310, 313 and 314, weight 505 - 547 kg, age 66 wks, mean dressing percentage ± S.E. 60.0 ± 0.6%) obtained from the "Studiecentrum voor Rundvleesproduktie" (Dir. Prof. em. J. Martin) were slaughtered in the slaughterhouse of our laboratory, split into sides and one side from each carcass was stimulated (110 V, 0.1 - 0.6 Amps for 4 min.) within 1 h after killing. Both sides were kept for 22 h at ca. 15°C and then chilled for 24 h (Vandekerckhove et al 1978 a, 1978 b). Temperature and pH were measured at regular intervals. After chilling, samples of longissimus and latissimus muscles were obtained from three-rib cuts (Martin and Torreele, 1962) and used for determination of SL (Smith et al, 1971) and Warner-Bratzler shear values (Vandekerckhove et al, 1978 b) on both heated (Joseph, 1977) and raw samples.

Results and Discussion

Table 1 summarizes all results obtained. It is clear that electrical stimulation accelerates pH fall : final pH is reached ca. 4 h after stimulation in contrast to control sides. Rate of carcass cooling shows no significant difference due to stimulation, in contrast to the results of Bendall et al (1976) who observed slower cooling in stimulated carcasses.
In 8 samples (4 animals x 2 muscles), 4 samples showed significantly lowered shear force values measured on heated muscles due to stimulation, whereas in 1 sample a significantly higher value was obtained. In two samples only a concomittant significant increase in SL was observed. In one sample sarcomere length was significantly decreased by stimulation (latissimus animal 313). These results contrast with earlier results, involving prevention of cold shortening, where increased tenderness due to stimulation was always associated with increased SL (Vandekerckhove et al, 1978 b). Although considerable variability in the data is apparent, the results do suggest that electrical stimulation may have a tenderizing effect in beef muscle, quite apart from the prevention of cold shortening and not related to differences in SL. This confirms data obtained by Savell et al (1977) and Smith et al (1977). That the increase in tenderness obtained in this experiment is of different nature than that of increases obtained in our earlier work(associated with increases in SL) is also apparent when shear force values on raw and heated muscle are compared. From the data in table 1 obtained using longissimus, it is clear that when electrical stimulation increases tenderness of heated muscle, this increase is also reflected in raw muscle (animals 309 and 314). In contrast, increased tenderness of heated muscle due

TABLE 1 Effect of electrical stimulation on rate of pH fall, muscle sarcomere length and tenderness[d]

Animal	309		310		313		314	
	L↯[e]	R	L↯	R	L↯	R	L↯	R
$-\Delta pH_4$[a]	1.17	0.37	1.30	0.80	1.20	0.92	1.30	0.83
$-\Delta pH_{23}$	1.15	1.08	1.29	1.27	1.20	1.20	1.25	1.25
$-\Delta t_4$ (°C)	9.0	7.6	6.8	8.4	7.1	6.2	7.1	8.0
$-\Delta t_{23}$ (°C)	22.1	22.2	22.7	23.3	22.2	21.9	22.5	22.5
Longissimus								
SL[b] (μ)	1.82[x]	1.67	2.12	1.99	1.97	1.93	1.69	1.72
WB[c] (kg)								
heated	5.55[xxx]	6.64	5.52	5.67	4.88[xxx]	3.82	4.51[xxx]	5.38
raw	5.72[xxx]	7.97	5.33[x]	6.74	6.67	6.78	5.68[xxx]	7.78
Latissimus								
SL (μ)	3.37[xxx]	2.79	3.00	3.03	2.31[xxx]	2.90	3.14[xxx]	2.37
WB (kg)								
heated	5.40	5.38	2.70[xxx]	3.05	5.49	5.32	3.08[xxx]	4.58

a $-\Delta pH_4$ = pH drop observed ca. 4 h after dressing (initial pH 6.61 ± 0.02)

$-\Delta t_4$ = temperature drop observed ca. 4 h after dressing (initial temp.: 36.8 + 0.2°C)

b SL = sarcomere length ; c WB = Warner-Bratzler shear force ; d = mean values only

e L↯ = left sid was stimulated

x significant at $p < 0.05$; xxx significant at $p < 0.001$

TABLE 2 Effect of electrical stimulation on tenderness of raw and heated muscle[a]

Animal	I		II		III		IV		V		VI	
	L↯[d]	R	L↯	R	L↯	R	L↯	R	L↯	R	L↯	R
Longissimus												
SL[b] (μ)	2.24[xxx]	1.88	1.89[x]	1.73	2.02[xx]	1.89	2.17[xxx]	1.84	1.96[xxx]	1.77	2.03[x]	1.89
WB[c] (kg)												
heated	4.0[xxx]	5.6	6.2	6.2	5.6[xxx]	6.3	7.6[x]	8.0	3.6[xxx]	4.3	5.6[xxx]	7.1
raw	5.7	5.6	6.9	6.2	11.1[xxx]	8.0	7.8[xxx]	4.8	6.0	5.0	8.0	7.1

a Data obtained in expt. II described by Vandekerckhove et al (1978 b)(mean values)

b SL = sarcomere length

c WB = Warner-Bratzler shear force

d L↯ = left side was stimulated

x significant at $p < 0.05$

xx significant at $p < 0.01$

xxx significant at $p < 0.001$

to electrical stimulation and associated with increased SL, was associated with decreased tenderness of raw muscle in our earlier experiments (Vandekerkhove et al, 1978 b) (table 2). As young animals (13 months) were used in this experiment, the latter results are in agreement with the increase in shear force value (decreased tenderness) observed in raw meat with decreased degree of shortening for young ox (Davey and Gilbert, 1975). The reason for the tenderizing effect of electrical stimulation, not involving changes in SL are not clear. The more rapid fall of pH results in lower pH values at higher temperatures in stimulated sides and may cause disruption of lysosomal membranes with release of acid hydrolases as suggested by Savell et al (1977). Changes in collagen involving an increase in the amount of smaller molecular weight subunits and of total extractable collagen such as those taking place during conditioning of meat (Dutson, 1974) may be accelerated by electrical stimulation. The absence of a consistent tenderizing effect in our experiment agrees with the findings of Savell et al (1977) and may also be related to differences in electrical stimuli received by the muscles in each carcass.

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