The Effect of High and Low Voltage Electrical Stimulation on Beef Quality

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Introduction

Electrical stimulation has been reported to be an effective method for improving meat tenderness, although its mechanism has bot been fully elucidated. The increased rate of glycolysis and earlier onset of rigor mortis has been shown to reduce the toughening effects of cold shortening and thaw rigor (Carse, 1973; Chrystall & Hagyard, 1976 and Davey et al., 1976).

Since differences in tenderness not associated with differences in sarcomere length have been found, it was suggested that electrical stimulation enhances tenderness by mechanisms other than or in addition to prevention of cold shortening (Savell et al., 1977, 1978; Smith et al., 1977). Postulated mechanisms include physical disruption of muscle fibres (Savell et al., 1978), increased lysosomal enzyme activity (Dutson et al., 1978) and diminution of collagen cross-links (Judge et al., 1980).

Most of the studies on electrical stimulation cited above involved the application of high voltages. However, a number of authors (Jonsson et al., 1978; Nilsson et al., 1979; Bouton et al., 1980) have demonstrated a similar effect on pH fall with low voltage electrical stimulation techniques, although it was suggested that the resulting increase in tenderness was mainly due to the prevention of cold shortening. For safety reasons a low-voltage system is very attractive for application under commercial conditions.

The purpose of the present study was to compare the effectiveness of a high(300 V) and low(85 V peak) voltage early post mortem electrical stimulation under cooling conditions, which were supposed not to result in cold shortening.

Material and Methods

Twenty-four bulls of the Meuse-Rhine-IJssel (M.R.Y.) breed of approximately 1½ years of age, were randomly assigned to each of the following treatments. Eight animals were stimulated via the nostrils and shackle immediately after debleeding (5-10 minutes post mortem) with a low voltage (85 V peak, 14 Hz; continuous) for one minute, using commercially available equipment (Mitab, Simrishamm, Sweden). Eight animals were stimulated immediately after debleeding and decapitation with a high voltage (300 V, 50 Hz; impulses of 2½ sec. and 1½ sec. interval) for a total of 1½ minute via electrodes mounted in the tail and neck region. Eight animals served as untreated controls.

The pH and temperature of the M. adductor and M. longissimus were determined at 1, 2, 4, 6, 8 and 24 hrs post mortem at about 2.5 cm below the surface.

At 24 hrs post mortem samples of approximate 800 gram were removed from the longissimus at the 8-10th rib of one side of the stimulated carcasses and on both sides of the control carcasses. From five randomly distributed locations on the exposed cross section of the muscle, samples were collected for replicate measurements of sarcomere length, using the laser diffraction technique described by Voyle (1971). Muscle samples were weighted, vacuum-packed and stored at 2°C.

At day 7 post mortem drip-loss and colour (Hunter photometer; L, a and b values) were determined and samples were heated in a waterbath until a central core temperature of 70°C was reached. The samples were cut in a longitudinal direction using a mechanically driven borer. From each sample ten cores were used for shear force measurements, using a Warner-Bratzler operating head mounted in an Instron Universal Testing machine. Peak or maximum shear force was expressed in kg/cm^2. Similarly prepared cores were used in preference tests for tenderness by a trained 10-member taste-panel.

Data were subjected to a one-way analysis of variance, after per carcass averaging of available replicate measurements. Differences between treatments were tested using t-tests on a pooled estimate of the variance of carcasses within treatments.

For the preference tests blocks were formed consisting of one carcass from each treatment. Within each block paired comparisons of control, low and high voltage samples were made by the taste-panel. Each pair of samples was ranked and scored (scale 1-10) by each panel-member for tenderness. The weighted averages within blocks of the direct and indirect estimates of each difference were subjected to a random model two-way analysis of variance, the two criteria of classification being blocks and panel-members. A test for the mean value of each difference was obtained by calculating the appropriate combination of components of variance of blocks, panel-members and residual variance.

The statistical analysis of the data was based on well known general methods (Snedecor and Cochran, 1967).

Results and Discussion

Table 1 presents the means of carcass characteristics and measurements for the various groups. No significant differences were found between the groups.

Table 1. Means for carcass traits.

Trait	Low voltage	High voltage	Control	S.E. of difference
Warm carcass weight (kg)	333	324	326	9
Subcutaneous fat cover score (scale 1-5)	2.91	3.00	2.92	.14
Carcass muscling score (scale 1-5)	4.05	3.96	3.84	.14

The results of pH and temperature measurements are presented in table 2. One of the animals of the low voltage stimulation group exhibited post mortem dark, firm and dry (DFD) meat with an ultimate pH of 6.9 in the longissimus muscle. Since this condition considerably influences the various parameters under investigation, all data from this animal were excluded from the analysis.

Table 2. Mean pH and temperature data for longissimus and adductor muscle.

Muscle	Time post mortem (hr)	pH			Temperature		
		Low voltage	High voltage	Control	Low voltage	High voltage	Control
Longissimus	1	5.96[a]*	6.02[a]	7.08[b]	37.2[a]	38.1[b]	37.1[a]
	2	5.81[a]	5.71[a]	6.68[b]	32.1	32.6	31.7
	4	5.69[a]	5.65[a]	6.19[b]	23.8	23.5	24.2
	6	5.69[a]	5.61[a]	5.99[b]	18.1	19.0	18.4
	8	5.66[a,b]	5.59[a]	5.80[b]	14.9	15.1	14.8
	24	5.66	5.61	5.68	3.4	3.0	3.1
Adductor	1	5.96[a]	6.05[a]	6.86[b]	38.9	38.7	38.3
	2	5.64[a]	5.79[a]	6.45[b]	32.7[a,b]	33.9[a]	31.7[b]
	4	5.63[a]	5.60[a]	6.01[b]	27.4	27.4	26.3
	6	5.57[a]	5.52[a]	5.84[b]	22.5	22.4	22.5
	8	5.53[a]	5.49[a]	5.68[b]	18.7	19.2	19.5
	24	5.54[a]	5.52[a]	5.58[b]	6.9[a,b]	6.6[a]	7.6[b]

* a, b, c means with different superscript differ significantly ($P < 0.05$)

Both stimulation methods resulted in a significantly more rapid pH fall during the first 8 hrs post mortem, both in the longissimus and adductor muscle. At one hour post mortem, pH in the stimulated carcasses was approximately 6.0. The pH of the adductor muscle was also significantly lower at 24 hrs post mortem. At all times non-significant differences were observed in pH values between both groups of stimulated carcasses. In some instances significantly higher temperatures were recorded in muscles of stimulated carcasses during the very early post mortem period.

Combination of the results of pH and temperature measurements show that in the control animals the average pH was already below 6.0 at 6 hrs post mortem, while the temperature at that time was still 18 and 22°C in the longissimus and adductor muscle, respectively. Accepting Bendall's (1972) description of cold shortening conditions as correct ("temperature below 11°C before the pH has fallen below 6.2"), cold shortening should not be present in these animals. In fact, when extra polating to 10 hrs post mortem, muscle temperature conditions ('ten' & 'ten' rule) are reached which ensure an optimum tenderness, according to the same author.

In table 3 the results of sarcomere length, colour, drip, cooking loss and maximum shear force measurements of the longissimus samples, are reported. No significant differences were observed between low and high voltage stimulated samples in any of these characteristics.

Table 3. Means for longissimus muscle traits.

Trait	Low voltage	High voltage	Control	S.E. of difference
Sarcomere length (µm)	1.63[a]	1.61[a]	1.43[b]	.06
Drip loss (%)	2.76[a]	2.76[a]	1.77[b]	.25
Colour (Hunter) L value	32.0[a]	33.2[a]	29.7[b]	1.4
a "	14.6[a]	14.9[a]	13.4[b]	.6
b "	7.3[a]	7.7[a]	6.4[b]	.6
Cooking loss (%)	26.1[a]	25.8[a]	21.4[b]	1.3
W.-Br-shear force (kg/cm^2)	4.59[a]	3.87[a]	5.77[b]	.42

Sarcomere length was found to be significantly shorter in control than in stimulated carcasses, an observation which was unexpected for reasons mentioned above.

Although Warner-Bratzler maximum shear force values were indeed significantly lower in the stimulated samples as compared with the control samples, electrical stimulation also resulted in a one percent increase in drip loss during vacuum storage from 1-7 days post mortem and a 4.5 - 5 per cent increase in cooking loss.

The results of tristimulus colour measurements with the Hunter apparatus show higher L, a and b values for stimulated samples indicating that the treatment resulted in a brighter red colour of the meat.

In table 4 the results of the taste-panel tests are summarized. The critical levels refer to one-sided tests for comparisons of stimulated with control carcasses.

Table 4. Results of taste panel tests.

Comparison	Estimated preference for 1st treatment	S.E.	P*	Estimated difference in tenderness score	S.E.	P*
Low voltage vs.control	73%	8%	.01	+.72	.23	.01
High voltage vs.control	65%	8%	.05	+.56	.25	.04
Low voltage vs.high voltage	58%	9%	.38	+.16	.20	.46

* one sided alternative for low voltage vs. control and high voltage vs. control.

When ranked and scored for tenderness both low and high voltage stimulated samples were found to be significantly superior to control samples. In total, low and high voltage samples are estimated to be prefered above control samples in 73% en 65% of all preference tests, respectively. No significant differences were found between the two stimulation methods in ranking or scoring in the preference tests.

The results presented here suggest that the effects of early post mortem high and low voltage electrical stimulation on various meat quality characteristics, including tenderness, are not different.

Although the results of pH and temperature measurements suggest an absence of cold shortening conditions, a lower sarcomere length was found in the muscles of the control animals. A possible explanation might be that the rate of temperature decline in the longissimus, although relatively slow, still exerts some shortening effect in the control animals. Support for this assumption is found in more recent experiments (Smulders et al., data to be published) in which, under cooling conditions similar to those in the present experiment, a significant effect of high voltage electrical stimulation on tenderness was shown in the M. longissimus, M. triceps brachii and M. adductor. However, no coincident effect on sarcomere length was observed in the latter two muscles. The differential rate in post mortem temperature decline between the various muscles, as illustrated in table 2 for the longissimus and adductor muscle, might possibly explain these conflicting results.

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References

BENDALL, J.R. (1972). Meat Chilling - Why and How?, p.3.1. Meat Research Institute Symposium, No.2, Langford, Bristol.

BOUTON, P.E., FORD, A.L., HARRIS, P.V. and SHAW, F.D. (1978). J.Food Sci., 43, 1392.

CARSE, W.A. (1973). J.Fd.Technol., 8, 163.

CRYSTALL, B.B. and HAGYARD, C.J. (1976). N.Z.J.Agric.Res., 19, 7.

DAVEY, C.L., GILBERT, K.V. and CARSE, W.A. (1976). N.Z.J.Agric.Res., 19, 13.

DUTSON, T.R., SMITH, G.C. and CARPENTER, Z.L. (1980). J.Food Sci., 45, 1097.

JONSSON, G., FABIANSSON, S. and NILSSON, H. (1978). Proc. 24th European Meeting of Meat Res.Workers, Kulmbach, E 10, 3.

JUDGE, M.D., REEVES, E.S. and ABERLE, E.D. (1980). Proc. 26th European Meeting of Meat Res.Workers, Colorado Springs, 2, J3.

NILSSON, H., RUDERUS, H. and FABIANSSON, S. (1979). Proc. 25th European Meeting of Meat Res.Workers, Budapest, 2.2.

SAVELL, J.W., SMITH, G.C., DUTSON, T.R., CARPENTER, Z.L. and SUTER, D.A. (1977) J.Food Sci., 42,702.

SAVELL, J.W., DUTSON, T.R., SMITH, G.C. and CARPENTER, Z.L. (1978). J.Food Sci., 43, 1606.

SMITH, G.C. DUTSON, T.R., CARPENTER, Z.L. and HOSTETLER, R.L. (1977). Proc.Meat Ind.Res.Conf., Amer.Meat Inst. Foundation, Chicago, IL, p.147.

SNEDECOR, G.W. and COCHRAN, W.G. (1967). Statistical Methods, Sixth ed. The Iowa State University Press, Ames, Iowa.

VOYLE, C.A. (1971). Proc. 17th European Meeting of Meat Res.Workers, B4, 95.