EFFECT OF LOW VOLTAGE ELECTRICAL STIMULATION ON HOT PROCESSED PORK LOINS

A.J. MØLLER[1], E. KIRKEGAARD[1] AND T. VESTERGAARD[2]

[1]Royal Vet.- and Agricultural Univ., Inst. Meat Technology and Process Engineering, Howitzvej 11, DK-2000 Copenhagen F, Denmark

[2]National Inst. of Animal Science, Foulum, P.O.Box 39, DK-8830 Tjele.

INTRODUCTION

Post mortem electrical stimulation (ES) of carcasses as a process for improving meat tenderness has received considerable interest to enhance the quality of mainly beef and lamb. ES in the early post mortem period has been suggested to tenderize the meat by preventing cold shortening and/or by causing physical disruption of the muscle fibers (Marsh, 1986).

Rather limited data have been published about ES of pork and its use in the industry has been considered uncertain because ES may enhance the development of pale, soft and exudative (PSE) meat. Westervelt & Stouffer (1978) and Johnson et al.(1982) reported, however, only slight differences in lean color and tenderness between ES vs control pork carcasses. Crenwelge et al. (1984) and Reagan & Honikel (1985) indicated that ES can induce a PSE like condition but rapid chilling combined with ES lessened this detrimental effect. Gigiel & James (1984) reported that toughness in pork loins, induced by a rapid chilling system before boning at approximately 4 hr post mortem, could be eliminated by ES but samples from these muscles were slightly paler and more watery than unstimulated controls. While previous studies involved the application of high voltage ES, the purpose of this work was to evaluate the effect of a low voltage electrical stimulation system (LVES) combined with different delay time before early boning upon some biochemical changes and meat quality parameters of pork loins.

MATERIALS AND METHODS

52 marked weight pigs, approximately 90 kg live weight, with mean backfat thickness 19 mm (range 15-25 mm) were stunned with carbon dioxide and randomly assigned to nonstimulated controls or LVES treatments. LVES was applied immediately after sticking and during bleeding for either 2 or 4 sec with the Swedish Mitab system (85 v, 14 Hz). The current was applied via clips attached to the nostrils and tail. After stimulation, carcasses were dressed and split using conventional abbatoir procedures and then conditioned at 2-4°C for various length of time before boning. The M. longissimus dorsi (LD), 9-15 rib, from both sides were used to obtain four equal sections, approximately 250 g, and randomly assigned to be removed from the carcass at 1, 3, 5 or 9 hr post mortem. After various measurements as indicated below, LD sections were trimmed for subcutaneous fat, wrapped in polyethylene bags and totally immersed in ice water at 0°C until 24 hr post mortem. Then a 10 mm thick cross-section was cut for measuring sarcomere length and further 8-10 blocks (20x20x50 mm) with the length cut parallel to the muscle fibers were taken for Warner-Bratzler (WB shear force measurements. WB samples were placed in bags, vacuumized and randomly assigned to be stored at either 0 or 9 days at 2-4°C, then kept at -20°C for 8-12 weeks before measurements.

Temperature, pH, ATP, R-values and probe values were measured on the LD sections at intervals during chilling. The pH values were measured using a Knick Digital model 653 and direct insertion probe electrode. Perclorid acid extracts were produced and used for ATP determination by the luciferin-luciferase method (Wolstrup & Jensen, 1976) and also for measuring R-values as an estimation of the degree of transformation of ATP to IMP (Honikel & Fischer, 1977). Internal reflectance, i.e. probe value, was recorded with the Danish Portable Probe Instrument (Andersen, 1984) by utilizing a wavelength near the infrared region, i.e. 940 nm.

The weight of trimmed LD sections were obtained before cooling at 0°C and

upon completion of the initial chilling period at 24 h post mortem for calculating percent drip loss. A helium-neon laser with a wavelength of 632,8 nm was used for measurements of sarcomerelengths. WB samples were heated in a waterbath at 80°C for 25 min and an Instron Universal testing machine (model 4301) was used to measure the peak shear force (N/cm^2).

Analysis of variance was used to estimate the significance of the main effects of treatments. Least significant differences were obtained using the error term from the analysis of variance.

RESULTS & DISCUSSION

Temperature and pH

Muscle pH and temperature were measured in the center of loin sections after boning and at selected times post mortem during chilling in ice water. There was no significant difference in temperature between control and LVES treatment at any time tested. For the 1 h hot boned loin sections, temperature dropped below 10°C at approximately 3 h post mortem while temperatures for delayed boned loins at 3, 5 or 9 h post mortem reached 10°C at respectively 4.3, 5.4 and 6.0 h post mortem.

The pH decline with time post mortem showed large variation between carcasses for both control and LVES treatments. At 45 min post mortem, pH dropped to 6.11 ± .32, 5.99± .35 and 5.83 ± .35 for respectively controls, 2 and 4 sec LVES treatments. These pH values from stimulated muscles are somewhat higher than found in earlier reports from where pH 5.6 - 5.7 at 1 h post mortem were obtained by using high voltage systems (Gigiel & James, 1984; Reagan & Honikel, 1985; Neel et al., 1987).

An analysis of variance on pH values showed no significant interaction between treatments. Mean values of pH as stratified by post mortem treatments are reported in table 1. As shown, pH values decreased as a result of LVES treatment, however, only significantly ($P < .05$) for the 4 sec LVES treatment. As expected, the pH declined significantly ($P < .05$) by increased time of delay before boning. Honikel et al. (1984) reported that the development of rigor in porcine muscles occurs at pH 5.9. The latter study implies that muscles could be rapidly chilled at this point of the rigor process without the occurrence of severe cold shortening. Following that, rapid chilling of loin sections from the present experiment should be feasible at 1 h post mortem for the 4 sec LVES treatment or at approximately 3 h post mortem for the controls.

ATP and R-values

Changes in the concentrations of ATP as affected by treatments are shown in table 1. A higher concentration of ATP was found in controls than in LVES samples but significantly only ($P < .05$) when compared to the 4 sec LVES treatment. As the R-value is highly correlated with the ATP concentration (Honikel & Fischer, 1977), the 4 sec LVES treatment showed higher R-value and thus exhibited a more advanced stage of rigor development. According to the latter study, rigor mortis in porcine muscles occur at an ATP concentration of about 1.1 µmol/g muscle.

Drip loss and probe value

Mean values for percent drip loss and probe value are presented in table 2. LVES treatment and delay time of 5 to 9 h before boning increased drip loss significantly ($P < .05$) as compared to controls but the maximum of 1.3% drip loss would not be considered excessive. The higher level of drip loss values from LVES treatment would be expected since this treatment lowered the muscle pH more rapidly within 1 h post mortem at internal muscle temperature above 35°C. Similar results have appeared from earlier reports (Gigiel & James, 1984; Reagan & Honikel, 1985) while Neel et al. (1987) did not observe significant effect on drip loss by electrical stimulation for accelerated processed bone-in

loins. Reagan & Honikel (1985) also indicated the advantage of fast chilling of stimulated muscles as an effort to reduce a possible negative effect on purge and color. In agreement to this, the lowest values for drip loss in the present study were exhibited by loins which were chilled most rapidly, i.e. after being boned at 1 or 3 h post mortem. In the 1 h deboned, rapidly chilled loin samples to temperature below 10°C within 3 h post mortem, cold shortening could have taken place and caused higher drip loss values. Due to our sampling procedure, however, drip loss was evaluated after only 24 h of storage which may have resulted in an underestimation of drip loss as affected by cold contracture (Honikel et al., 1986).

Probe values increased significantly ($P < .05$) as due to 4 sec LVES treatment and when time of delay before boning was increased to above 5 h. The actual level of probe values were within the normal range as a value of 80 are normally used as the borderline between PSE and normal type of pork.

WB shear values and sarcomere length

Mean values for WB shear force and sarcomere length stratified by post mortem treatment are reported in table 3. Sarcomere length increased significantly ($P < .05$) due to LVES treatment and time of delay before boning although the magnitude of the differences were small. WB values were not significantly affected by LVES treatment which is in agreement with previous work using high voltage electrical stimulation systems (Johnson et al., 1982; Reagan & Honikel, 1985; Neel et al., 1987). However, Gigiel & James (1984) reported that toughness in pork loins induced by a rapid chilling system could be eliminated by electrical stimulation.

Based upon our previous taste panels, WB values above 60 N/cm^2 are normally regarded as being slightly tough. As seen from table 3, acceptable tenderness level was obtained in this experiment only if a delay time of 5 h had been used before boning. Although the risk of cold shortening was expected to be diminished for stimulated muscles, acceptable tenderness - even by 4 sec LVES treatment - were not found unless a 5 h delay time was inserted before boning and rapid chilling. It must be noticed, however, that the method used in the present experiment of inducing maximum cold shortening by immersion of excised muscles in ice water perhaps represents a more drastic treatment than is likely to occur under commercial chilling conditions.

No significant interaction between post mortem treatment and ageing on WB shear force values appeared from this study. As shown in table 3, a significant tenderness improvement was observed for loin sections between 0 and 9 days of storage at 2-4°C.

CONCLUSION

The results of the present data on hot processed pork indicate that low voltage electrical stimulation applied immediately after sticking for a period of 4 sec significantly increase the glycolytic changes in the loin muscle post mortem. Stimulated muscles were slightly paler and watery while tenderness, regardless of delay time from 1 to 9 h before boning, was not beneficially affected by the use of low voltage electrical stimulation. Rapid chilling of loins boned within 5 h post mortem detrimentally effects tenderness while the advantages include improved color and waterbinding.

Table 1 - Ls means of pH, ATP and R-value in M. longissimus dorsi as affected by electrical stimulation and delay time before boning.

	pH[1]	ATP[1]	R-value[1]
Stimulation[2]			
control	5.83^{a}	2.03^{a}	1.15^{a}
LVES 2	5.78^{a}	1.82^{a}	1.17^{a}
LVES 4	5.63^{b}	1.18^{b}	1.30^{b}
Delay time (h) before boning			
1	5.92^{a}	3.28^{a}	1.06^{a}
3	5.80^{b}	1.79^{b}	1.21^{b}
5	5.69^{c}	1.18^{c}	1.25^{b}
9	5.57^{d}	.46^{d}	1.31^{c}

[1] values represents measurements at time of boning.

[2] control - nonstimulated, LVES 2 and LVES 4 - low voltage electrical stimulation for resp. 2 or 4 sec.

a, b, c, d Means bearing different superscripts are significantly different ($P < .05$).

Table 2 - Drip loss and probe values in M. longissimus dorsi as affected by electrical stimulation and delay time before boning. (Ls means).

	Drip loss,%	probe values
Stimulation[1]		
control	.80^{a}	62.61^{a}
LVES 2	1.15^{b}	64.81^{a}
LVES 4	1.34^{b}	72.29^{b}
Delay time (h) before boning		
1	.83^{a}	61.47^{a}
3	1.03^{a}	63.74^{a}
5	1.30^{b}	70.55^{b}
9	1.23^{b}	70.51^{b}

[1] see table 1.

a, b Means bearing different superscripts are significantly different ($P < .05$).

Table 3 - Sarcomere length and Warner-Bratzler shear force values (WB) as affected by electrical stimulation, ageing and delay time before boning. (Ls means).

	Sarcomere length, µ	WB values N/cm^2
Stimulation[1]		
control	1.68^{a}	59.88^{a}
LVES 2	1.71^{b}	62.22^{a}
LVES 4	1.72^{b}	61.72^{a}
Delay time (h) before boning		
1	1.68^{a}	69.46^{a}
3	1.69^{a}	64.75^{b}
5	1.73^{b}	55.88^{c}
9	1.72^{b}	55.04^{c}
Ageing, days at 2-4°C		
1	-	65.43^{a}
7	-	57.12^{b}

[1] see table 1.

a, b, c, d Means bearing different superscripts are significantly different ($P < .05$).

REFERENCES

Andersen, I.E. (1984):
Some experience with the portable Danish probe for the measurement of pig meat quality. Proc. Scient. Meeting "Biophysical PSE-muscle analysis", Vienna, Austria.

Crenwelge, D.D., Terrell, R.N., Dutson, T.R., Smith, G.C. & Carpenter, Z.L. (1984):
Effect of chilling method and electrical stimulation on pork quality. J. Animal Sci. 59, 697.

Gigiel, A.J. & James, S.J. (1984):
Electrical stimulation and ultra-rapid chilling of pork. Meat Sci. 11, 1.

Honikel, K.O. & Fischer, C. (1977):
A rapid method for the detection of PSE and DFD porcine muscle. J. Food Sci. 42, 1633.

Honikel, K.O., Kim, C.J. & Hamm, R. (1984):
The influence of temperature on post mortem changes in porcine muscles. Proc. 30th European Meeting of Meat Res. Workers. Bristol, England, p. 95.

Honikel, K.O., Kim, C.J., Hamm, R. & Roncalés, P. (1986):
Sarcomere shortening of prerigor muscles and its influence on drip loss. Meat Sci. 16, 267.

Johnson, D.D., Savell, J.W., Weatherspoon, L. & Smith, G.C. (1982):
Quality, palatability and weight loss of pork as affected by electrical stimulation. Meat Sci. 7, 43.

Marsh, B.B. (1986):
The tenderizing mechanisms of electrical stimulation. Proc. I.I.R. Symposium "Meat Chilling". Bristol, p. 39.

Neel, S.W., Reagan, J.O. & Mabry, J. W. (1987):
Effects of rapid chilling and accelerated processing on the physical and sensory characteristics of fresh pork loins. J. Anim. Sci. 64, 765.

Reagan, J.O. & Honikel, K.O. (1985):
Weight loss and sensory attributes of temperature conditioned and electrically stimulated hot processed pork. J. Food Sci. 50, 1568.

Westervelt, R.G. & Stouffer, J.R. (1978):
Relationships among spinal cord severing, electrical stimulation and post mortem quality characteristics of the porcine carcass. J. Anim. Sci. 46, 1206.

Wolstrup, J. & Jensen, K. (1978):
Adenosine Triphosphate and deoxyribonucleic acid in the alimentary tract of cattle fed different nitrogen sources. J. Appl. Bact. 45, 49.