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ELV Stimulation of Beef

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SUMMARY

Australian safety regulations state that unprotected electrical stimulation (ES) systems in abattoirs must use "extra low voltage" (ELV) which has an RMS voltage with a maximum of only 32V and a peak of 45V. Other countries permit peak voltages of up to 85V for their low voltage ES systems.

Two commercial ELV stimulation systems which meet Australian regulations were evaluated in four meatworks for their ability to prevent cold shortening. Both systems when introduced to Australian works, utilised a current pathway from the nose of the carcass to earth, via the shackle/roller/rail. A high percentage of meat samples from carcasses stimulated with the equipment in this configuration had a shear force value which exceeded 8 kg. An 8 kg shear force value has been designated by the CSIRO Meat Research Laboratory as the limit for acceptably tender meat.

Greater current flows through the carcasses were obtained when the carcasses were also earthed via the anus or the rump, that is, when earthed via another point in addition to the shackle/roller/rail pathway. A study was then made of the changes in meat shear force values which resulted from the use of three different current pathways through the carcass, altering the duration of stimulation and the siting of the nostril electrode and finally, the use of different "on/off" cycles.

In a large commercial trial, it was demonstrated that an ELV stimulator with a current pathway of either a nose-anal or a nose-leg bar system resulted in 95% of the *M. longissimus dorsi* samples having peak shear force values of less than 8 kg.

INTRODUCTION

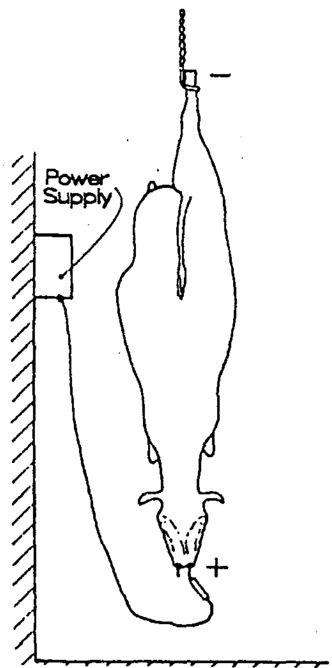

Figure 1: An ELV stimulation system which utilised a current pathway from nose to earth via the shackle and rails.

Unless Australian extra low voltage (ELV) safety regulations are met, ELV electrical stimulation (ES) systems require the same stringent safety procedures and precautions which are mandatory for high voltage systems. Current Australian ELV regulations state that the RMS voltage should be a maximum of 32V with a peak of 45V. These regulations differ from those overseas where, apparently, peak voltages of over 80V are acceptable (Ruderus 1980). This paper describes work carried out to evaluate two ELV stimulation systems which were in use in Australia and which utilised a current pathway from the nose to earth via the shackle/roller/rail (see Fig.1), and to investigate methods for improving the performance of these systems under commercial conditions.

MATERIALS AND METHODS

Experimental Procedures

Two commercial ES units were used. The AIS system employed a cycle of four 45V (peak) square wave pulses with alternating polarity of 25 ms pulse width, followed by a gap of 12.5 ms at zero potential. The Koch-Britton (KB) system employed 45V (peak) square wave pulses of 40 ms pulse width, continuous pulsing, with alternating polarity, and used a series of impulses: on for 3s, off for 1s. In

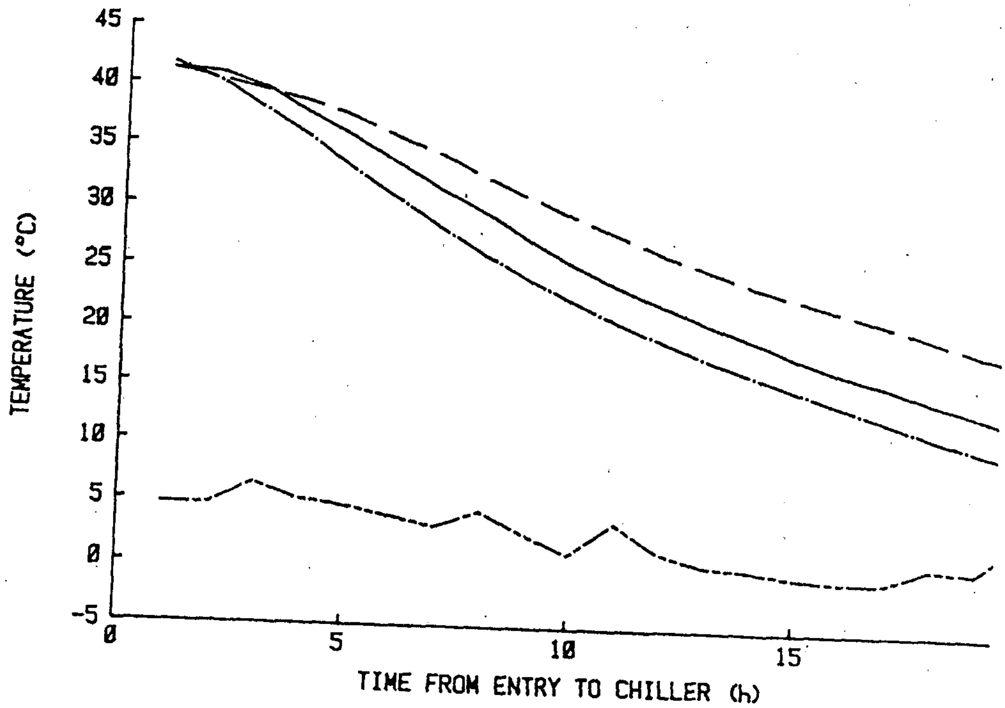

Figure 2: Deep butt temperatures following entry into the chiller of a typical side (110.0 kg, 7 mm fat; —), and of the slowest cooling side (135.6 kg, 8 mm fat; --) and fastest cooling side (95.6 kg, 5 mm fat; -·-) monitored. Over 50% of the carcasses monitored had temperatures within ± 2 °C of the typical curve shown at 20 h. The air temperature of the chiler is indicated by the line ——.

commercial use, both systems were used with a nose electrode and were earthed via the shackle/roller/rail. In the four works surveyed, one used the AIS system and three used the KB system.

The animals used for experiments 1 to 7 were 12 to 24 months old (checked by dentition at slaughter) and for experiment 8 were full mouth, third grade cows. Carcass weights ranged from 140 to 320 kg and had fat depths over the loin at the last rib, from 1 to 25 mm. Cattle used in experiments 1 to 7 had been selected as suitable for the local trade by abattoir cattle buyers. All animals were part of the commercial 'kill' at each meatworks and 50% were from feedlots.

Carcasses were stimulated within 4 min of slaughter and immediately after bleeding. Samples of *M. longissimus dorsi* (LD), described as pre-rigor, were removed from the carcasses within 2 hr of slaughter. Those samples described as post-rigor were removed after the carcasses had been chilled overnight at 0 to 5°C (i.e. at about 24 hr post-slaughter; see Fig.2). The pH of each muscle sample was measured at 1-2 hr and 24 hr post-slaughter, using a probe type combined electrode (Philips C64/1) and a Watson Victor 5004 portable pH meter.

Each sample was trimmed of extraneous fat and connective tissue, had a weight in the range 120 to 250 g and was placed in polyethylene bags. The pre-rigor samples were immersed in ice slush for 24 hr to induce cold shortening. Both pre-rigor and post-rigor samples were cooked at about 26 hr post-slaughter in polyethylene bags totally immersed in a water bath maintained at 80 ± 0.5°C for 1 hr.

Warner Bratzler (WB) shear force measurements were carried out using previously described techniques (Bouton & Harris 1978).

Experiment 1

To determine the effectiveness of one of the commercial stimulation systems in the nostril/shackle configuration (Fig 1), eighteen steers (0-2 tooth; carcass weight 150 11 kg; fat depth 2-5 mm) were assigned to three treatments. Six were assigned at random to:

(a)stimulation with the KB unit using time mode A (60s duration; 2s on / 1s off cycle);

(b) stimulation with the KB unit using time mode B (40s duration; 3s on / 1s off cycle);

(c) no stimulation.

For the non-stimulated (control) animals, one side of each carcass was hung via the Achilles tendon (CAT) while the other side was hung via the sacrosciatic ligament (tenderstretched; CTS).

All sides were chilled for 24 hr before the topside (*M.Semimembranosus* - SM), striploin (*M.Longissimus dorsi* - LD), rump (*Gluteus medius* - GM) and silverside (*Biceps femoris* - BF) were removed.

The deep pectoral (DP) and *semitendinosus* (ST) muscles were removed pre-rigor at 50 min and 70 to 90 min post-slaughter from all sides, except from those hung via the sacrosciatic ligament. In the latter case, the DP and ST muscles were removed post-rigor at 24 hr post-slaughter.

Experiment 2

To determine a profile of the tenderness of steaks from the carcasses produced typically in a meatworks, 93 carcasses were used at random in the second experiment. Thirteen were not stimulated and 80 were stimulated for 40s duration (3s on / 1s off cycle) using the KB unit with a nose electrode and a shackle/roller/rail earth. pre-rigor LD samples were taken from all 93 carcasses at approximately 90 min post-slaughter, and the post-rigor LD samples were taken from only 62 (51 stimulated, 11 non-stimulated) carcasses at 24 hr post-slaughter.

Experiment 3

The third experiment involved the calculation of carcass resistance. The current drawn by the carcass was measured with a cathode ray oscilloscope. Different earthing points on the carcass were evaluated for both the AIS and KB systems. A minimum of 15 carcasses were used in each configuration.

Experiment 4

To investigate alternative electrical earth sites and determine the optimum time for the application of ES, a total of 72 animals were used at random over nine treatment groups. The carcass treatments were:

(a) group one: non-stimulated;

(b) groups two and three: stimulated for 40s with the AIS and KB units respectively, used in the commercial mode, viz. with the nose electrode and a shackle/roller/rail earth.

(c) groups four to nine: stimulated with the AIS unit, either with an anal earth or a hand held earth which contacted the shackled leg in the vicinity of the rump for either 40, 60 or 80s (six treatments).

Samples of LD muscle were removed pre- and post-rigor as in experiment 2.

Experiment 5

This experiment was designed to investigate the effect of ELV ES with additional earthing configurations in a simulated production situation on the shear force values obtained for LD muscles removed pre- and post-rigor.

A total of 224 carcasses were used at random over four treatment groups. The carcass treatments were:

(a) non-stimulated (48 carcasses);

(b) stimulated using the KB unit for 40s in its normal nose-shackle/roller/rail configuration (54 carcasses);

(c) stimulated using the KB unit for 40s with an anal earth electrode (50 carcasses);

(d) stimulated using the KB unit for 40s with a handheld earth electrode which contacted the hide between the pinbone and stifle joint of the shackled leg, normally adjacent to the anus (72 carcasses).

Experiment 6

This experiment was designed to investigate the effect on the LD shear force values from differing means of attaching the KB system nose and shackle electrodes to the carcass.

A total of 134 carcasses were used at random over five treatment groups. The carcass treatments were:

(a) non-stimulated (40 carcasses);

(b) stimulated using the KB unit for 40s in the normal nose-shackle/roller/rail configuration (54 carcasses);

(c) stimulated as in (b) except the nose electrode was inserted through the distal part of the nasal septum (or the tip of the nose, 18 carcasses);

(d) stimulated as in (b) except the nose electrode was inserted in the stick wound (10 carcasses);

(e) stimulated as in (b) except the shackle chain had sharp projections which cut through the skin when the hock was shackled and the carcass hoisted (12 carcasses).

Samples of the LD muscle were removed post-rigor only, as in experiments 2 & 5.

Experiments 7 and 8

The manufacturer of the KB unit recommended that the system should stimulate a carcass for a total of 40s in a 3s on / 1s off cycle i.e. creating "impulses". These impulses were a cause of concern regarding worker safety and for the amount of mechanical stress this caused on the overhead structures. These experiments were designed to investigate the effect of different impulse cycles of the KB system on the WB shear values of the LD and ST.

In experiment 7, a total of 122 carcasses were used at random over five treatment groups. The carcass treatments were:

(a) non-stimulated (12 carcasses);

(b) stimulated using the KB system for 40s in its normal nose-shackle/roller/rail configuration (29 carcasses);

(c) stimulated as in (b) except the impulses of 3s on / 1s off were changed to 60 ms on / 20 ms off (30 carcasses);

(d) stimulated as in (c), with the addition of an earth electrode which contacted the hide of the shackled leg, normally adjacent to the anus (31 carcasses);

(e) a leg earth was used as for (d) except the time mode was changed to 120 ms on / 40 ms off (20 carcasses).

Samples of the LD muscle were removed post-rigor only, as in experiments 2 & 5.

In experiment 8, five carcasses were assigned (not at random) to each of four treatments. The carcass treatments were:

(a) non-stimulated;

(b) stimulated using the KB unit for 40s in its normal time mode of 3s on / 1s off;

(c) stimulated using the KB unit with power supplied continuously for 40s, i.e. no on/off cycle and the RMS voltage was the peak voltage;

(d) stimulated as in (c) except the power was supplied for 30s.

In this experiment, samples of the ST muscle were removed pre-rigor for each of the four treatments.

Experiment 9

To determine the effectiveness of high voltage ES when it is applied to carcasses suspended (shackled) by one leg in the bleeding area, a total of 110 carcasses were used (not at random) over three treatment groups. The carcass treatment groups were:

(a) non-stimulated (30 carcasses);

(b) high voltage (HV) 240V RMS, 350V peak, 14.3 pulses per second (pps) of half sine waves, used for 40s in the nostril-shackle/roller/rail configuration (40 carcasses);

(c) as for (b) except HV is 800V RMS, 1140V peak, 14.3 pps of half sine waves (40 carcasses).

Electrical stimulation was applied to the carcass within 7-10 min from stunning. Samples of the LD muscle were removed post-rigor as in experiments 2, 5 and 6.

Statistical Methods

Analysis of variance was used to establish the significance of the different treatments and to ascertain, where appropriate, the relevant standard errors and ,hence, least significant difference (LSD) values at the $P<0.05$ level.

RESULTS AND DISCUSSION

Experiment 1

The WB shear force measurements obtained for the SM, LD, GM and BF muscles from the non-stimulated sides and from both sides of carcasses stimulated in time modes A (60s duration; 2s on / 1s off cycle) and B (40s duration; 3s on / 1s off cycle) are shown in Table 1.

For the stimulated carcasses, the shear values did not differ significantly between similar muscles from free (F) or shackled (S) legs (during ES). The shear force values obtained for the SM and LD muscles from non-stimulated sides hung from the Achilles tendon (CAT) were high, indicating that chilling conditions had been severe enough in the commercial abattoir to produce cold shortening in at least those two muscles. With the exception of the BF, the values obtained for the restrained, non-stimulated (CTS) muscles were significantly lower than those obtained for the CAT muscles. The shear force values obtained for stimulated muscles were not, in general, significantly different from those obtained for the CTS muscles, but the mean values obtained for the stimulated SM and LD muscles were high.

The DP and ST muscles were removed 50 min and 70-90 min post-slaughter, respectively, and subjected to extreme chilling conditions in order to produce cold shortening. Muscle samples removed pre-rigor from stimulated carcasses had shear force values which were not significantly different from those obtained for CTS muscles removed post-rigor, and which were significantly ($P<0.001$) less than those obtained for the CAT muscles removed pre-rigor (Table 2). Again, ES gave the same tenderness response, whether the free or shackled leg was considered.

Pre-rigor excised DP and ST muscles subjected to cold shortening conditions appear to be useful in judging the efficiency of ES treatment. However, the tendency for both LD and SM muscles from carcasses stimulated with this system (nostril-shackle configuration) to be tougher than the same muscles from sides hung from the sacrosciatic ligament indicates that the DP and ST are atypical in their behaviour. Because of the this, the LD was selected as the muscle to evaluate the efficiency of ES throughout the remainder of this work.

Experiment 2

The results from experiment 2 in which the KB unit was used in the configuration recommended by the manufacturer are shown in Figs. 3 and 4.

Only a third of the pre-rigor samples and two-thirds of the post-rigor samples from stimulated carcasses were acceptably tender (WB shear force values less than 8 kg). There was a high proportion (about 20%) of carcasses with dark cutting meat (LD 24 hr pH values >5.9), but even if these were excluded, there was still an unacceptably high proportion (45%) of samples removed 24 hr post-slaughter from stimulated carcasses which were tough. When this experiment was repeated in three other works with similar cattle, but widely varying chilling conditions, similar results were obtained.

Experiment 3

From previous work with high voltage (HV) ES systems conducted at this Laboratory, it was known that the shin/hoof area has a high resistance to the passage of electrical current. If this area could be by-passed with the ELV systems which have a 45V peak limitation, then more power could be available to improve their effectiveness. The changes in resistance and current with the different placement of the earthing electrode for both KB and AIS units are shown in Fig. 5.

The change in relative resistance as the earth electrode was placed at different points on the carcass was again clear. Relative current decreased and resistance increased as the earth electrode was moved distally from the anus. This leads to the conclusion that the unsatisfactory results obtained

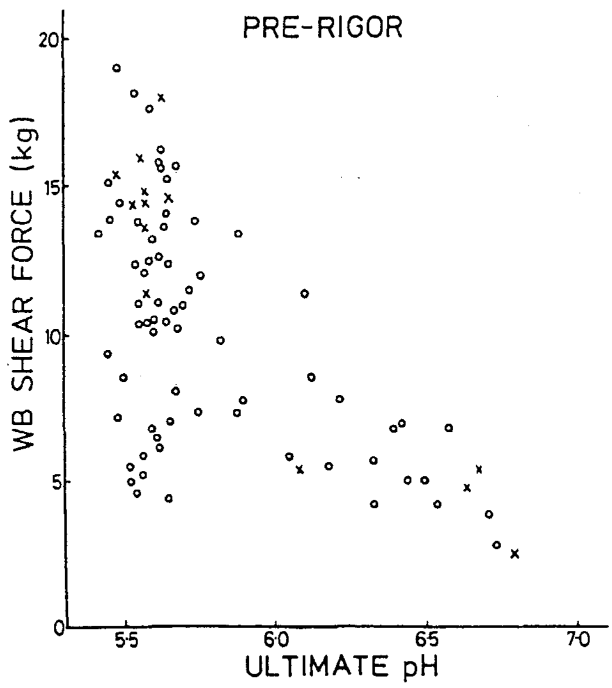

Figure 3: WB shear force results obtained for cooked stimulated (KB) samples (0) and control (X) LD pre-rigor muscle samples of different ultimate pH values.

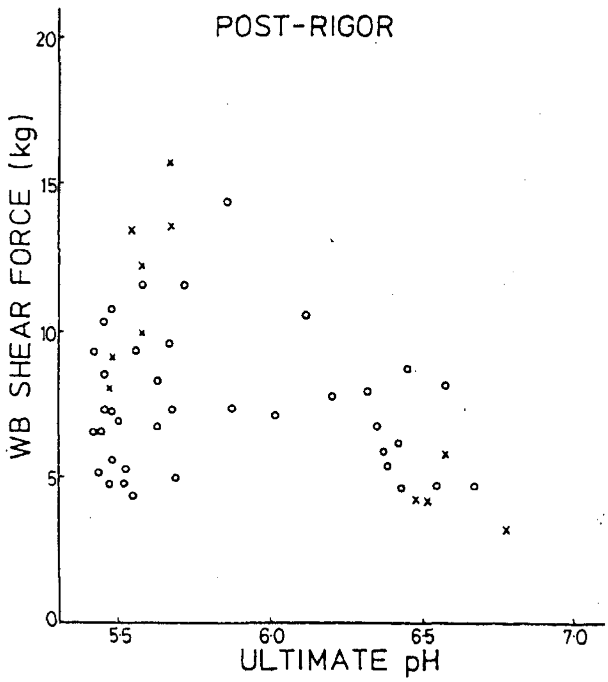

Figure 4: As for Figure 3, but with post-rigor samples.

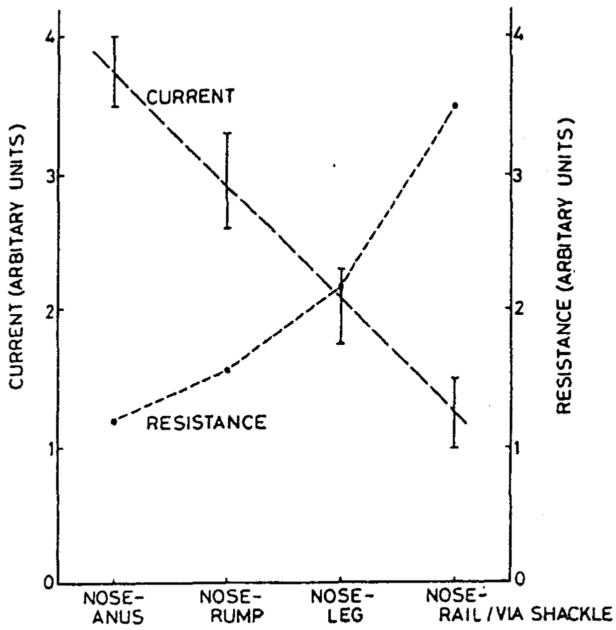

Figure 5: Relative changes in current and resistance for beef carcasses stimulated with KB and AIS systems using different earthing configurations. The rump earthing position was horizontal to the anus while the leg earthing position was approximately midway between the rump position and the knee joint.

in experiments 1, 2 and 4 where the KB and AIS units were used in a nose-shackle configuration may have resulted from the high resistance in the leg of the carcass.

Experiment 4

This trial was conducted:

(1)to confirm that increased current (power); and

(2)to determine the optimum time of ES which would result in an overall improvement and less variability in the shear values for the LD muscles.

The WB shear force and pH results are listed in Table 3.

The WB shear force and pH (2 hr) results obtained from meat stimulated with the AIS unit using an additional earth indicated that:

(a)the effect of stimulation when used with the additional earth significantly decreased the WB shear force and pH (2 hr) values relative to both the non-stimulated and the normal (shackle/roller/rail earth) stimulated samples;

(b) extending the duration of ES from 40 to 80s had no significant effect on post-rigor samples stimulated using either of the additional earthing configurations;

(c) for pre-rigor samples, an ES unit with an additional leg earth needed longer than 40s to be effective, i.e. there was a reduction in WB shear force values with increase in stimulation time.

From these results it was concluded that, provided an additional anal or rump earth was used during stimulation and that samples were removed post-rigor, a stimulation time of 40s was adequate. A point of interest was that although the stimulation systems in actual use at the meatworks (AIS and KB units with shackle/roller/rail earth) gave lower WB shear force and pH (2 hr) values than the non-stimulated samples, they both gave significantly higher values than those obtained using the AIS system with either an anal or a leg earth, i.e. stimulation without the additional earth was not fully effective.

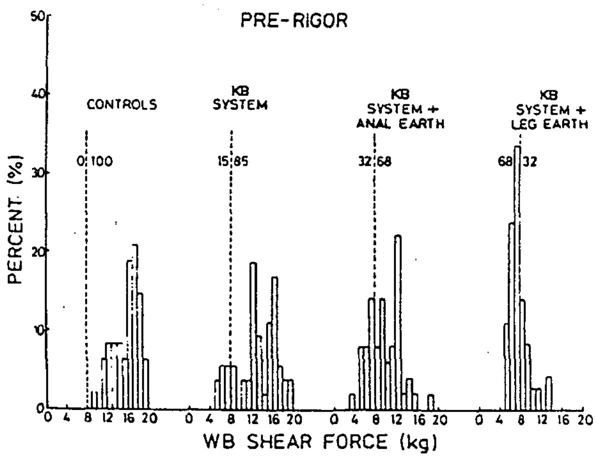

Figure 6: Number of samples having shear values in different ranges for LD muscles removed pre-rigor from carcasses which have been (A) unstimulated controls, (B) stimulated using KB system with normal shackle/rail earth , (C) stimulated using KB system with anal earth or (D) stimulated using KB system with a leg earth

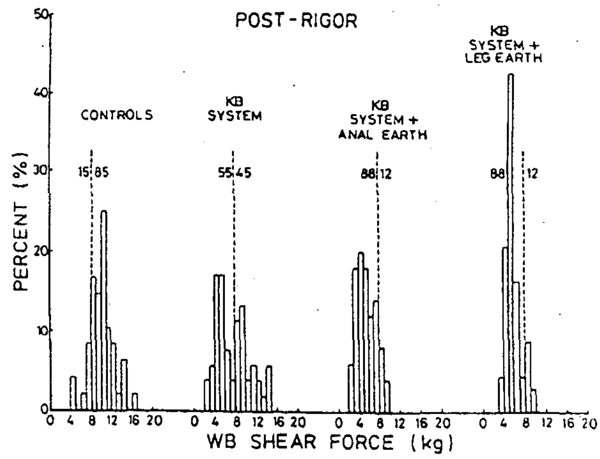

Figure 7: As for Figure 4 but with post-rigor samples.

Experiment 5

The meat tenderness profile results from a typical day's production in the meatworks are shown in Fig. 6 (pre-rigor) and Fig. 7 (post-rigor).

All of the non-stimulated pre-rigor samples and 85% of the non-stimulated post-rigor samples were unacceptably tough (shear force values of >8 kg). This indicates that without electrical stimulation, most LD muscles from these young animals (animals which had been selected by commercial buyers for supermarkets) would have been unacceptably tough.

Stimulation using the KB unit with a shackle earth improved meat tenderness, as 85% of the pre-rigor samples and 45% of the post-rigor samples had shear force values of >8 kg. The use of an additional earth electrode, whether via the anus or a rubbing electrode bar on the rump of the leg, further improved the tenderness so that only 12% of the post-rigor samples had shear force values of >8 kg. When those LD muscles having an ultimate pH of greater than 5.9 were excluded, less than 5% of carcasses stimulated with an anal or leg earth had shear values of >8 kg. For pre-rigor samples, 68% and 32% had values of >8 kg for the anal and leg earth systems respectively.

Experiment 6

Visually, carcasses responded identically to the application of power for the four stimulation treatments. However, the placement of the nose electrode in either the septum at the base of the nose or the stick wound resulted in no significant difference in the initial pH and the shear force values when compared with those for meat from non-stimulated carcasses (Table 4).

It is important to realise that it is impossible to observe any differences in the responses from the carcasses for each of the methods of attachment of the nostril electrode. That is, seeing a carcass respond to the application of electrical energy is no indication of successful electrical stimulation. Only when the electrode was inserted 100 mm or more into the nostril of the carcass was any protection from cold shortening conferred on the meat by the application of ES.

Experiments 7 and 8

There were no significant differences between the post-rigor shear values for the treatments cycles of 3s on / 1s off, 120 ms on / 40 ms off and 60 ms on / 20 ms off (Table 5). There was noticeable twitching of the muscles on the carcass when using the 120 ms / 40 ms cycle. When using the 60 ms / 20 ms (fast) time cycle, the carcass does not appear to contract and relax between each of the on/off cycles. Visually, to the eye of the operator, there is only one contraction when the system is switched on and one relaxation after the 40s of stimulation. As there is no difference in the shear values between the three different cycle treatments then clearly there is no contribution by the 10 major contractions and relaxations during the 40s of stimulation with the 3s on / 1s off cycle towards the prevention of cold shortening. The time power is on with the voltage at a peak of 45V is the significant factor.

This conclusion is also drawn from the shear values for the ST samples removed prerigor. In this case there is the expected significant difference between the WB values for samples from the normal KB system and the non-stimulated samples, no significant difference between the KB system treatments in the time modes 3s on / 1s off for 40s duration (the manufacturer's recommended procedure) and continuously on for 30s, and a significant difference between the time modes continuously on for 30s and continuously on for 40s (Table 5). For the latter case, the improvement in shear values is 30%, which corresponds to the increase in duration of the stimulation treatment to the carcass.

On the basis of these results it was considered that the construction of an additional earth for the KB and AIS systems to contact the rump area of a shackled leg of a carcass in the bleeding area, was relatively easy. It was important that the carcass received what appeared to be continuous stimulation; i.e. the additional earth which contacts the rump area must maintain an excellent contact with the carcass especially during the first contraction.

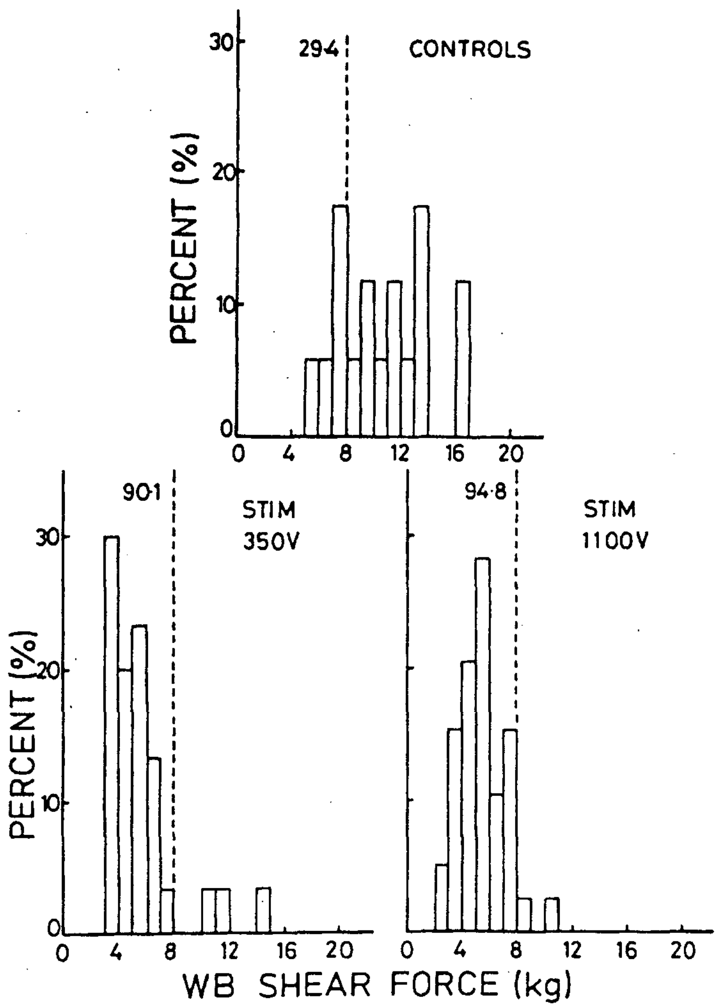

Figure 8: Number of samples having shear values in different ranges for LD samples removed post-rigor from carcasses which have been (A) unstimulated controls, (B) stimulated using high voltage 350 V peak, 14.3 pps of half sine waves for 40s in the nostril-shackle/rail configuration or (C) stimulated as for (B) except where peak voltage was 1140 V.

Comparison of ELV and HV

High voltage (HV) ES of carcasses immediately after sticking is not done commercially. However, it was of interest to know if HV had the capacity to overcome the problem of high resistance seen with the ELV units when the shackled leg was the pathway to earth. The results of the two HV systems studies are depicted in Fig. 8.

When a comparison is made of the histograms of WB shear force values for meat from the following:

- ELV stimulated carcasses (Fig. 7; KB system-leg earth);
- HV stimulated carcasses (Fig. 8; 350V and 1150V); and
- tenderstretched carcasses (Fig. 9; Powell *et al.* 1986),

it is apparent that the efficiency of ES systems to produce tender meat can be equated with that of the tenderstretch process.

Effective electrical stimulation

Electrical stimulation systems can improve tenderness significantly without being fully effective. It is not enough for the system to produce meat which is significantly more tender in a statistical sense than meat from non-stimulated, control carcasses. It is the absolute level of resulting tenderness which is important.

From theoretical considerations, it is to be expected that the benefits to tenderness in muscles subjected to ES will be:

- greatest in muscles free to shorten post mortem;
- greatest during the onset of rigor (i.e. during the first 24 hr);
- small when chilling conditions employed do not result in deleterious post mortem shortening in non-stimulated muscles;
- small, or non-existent, when the muscle has a high ultimate pH (i.e. pH>5.9).

Thus, if effective electrical stimulation is to be defined, reference must be made to the muscles used, the cooling rates employed, the ultimate pH of the muscle, the time post mortem when the muscle sample is taken, the tenderness standard used and the agreed proportion of carcasses of this or greater tenderness.

Moller *et al.* (1983) considered that an efficient ES system should result in muscles with shear values at least as low as those of contralateral muscles restrained from post mortem shortening,

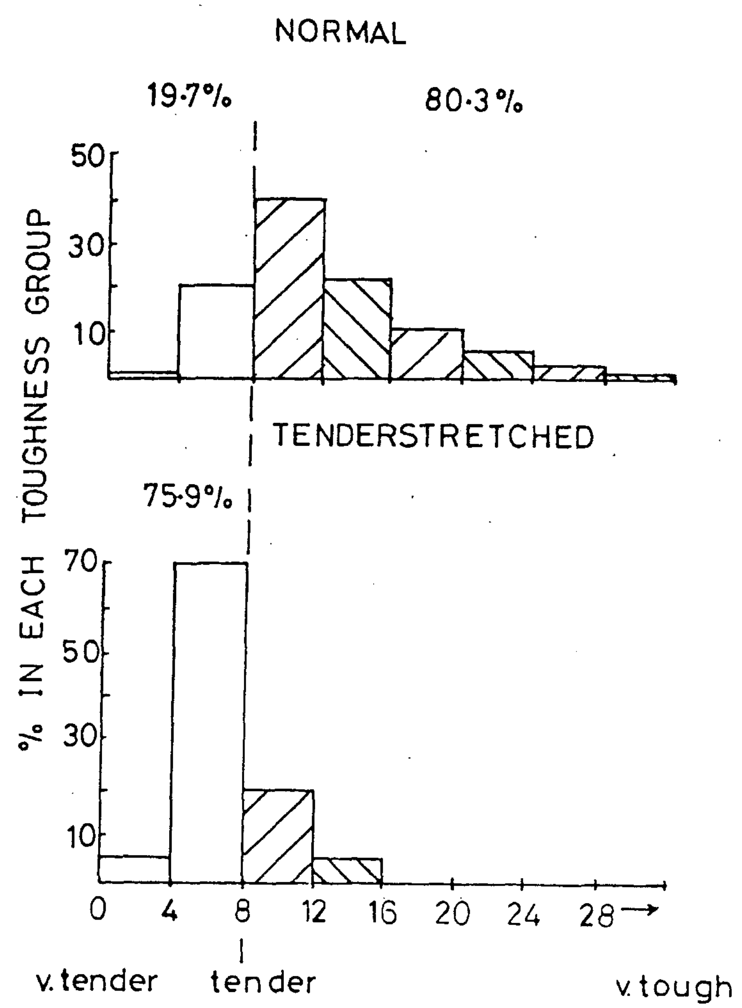

Figure 9: Toughness of striploins from normal and tenderstretched sides.

regardless of chilling conditions. Bouton *et al.* (1975) regarded meat samples removed from a carcass 24 hr post mortem, cooked using a standard laboratory procedure, and which had Warner-Bratzler initial yield shear force values (IY) of >8 kg as measured on a modified Instron universal testing machine (Bouton *et al.* 1978) would be considered tough if eaten.

Our definition of an effective electrical stimulation system for beef is a system which gives IY values of <8 kg for the LD muscles from carcasses which have been chilled rapidly (less than 10°C at the centre of the LD in 10 hr), with at least 95% of the LD muscles having an ultimate pH<5.8 and which are cooked using a standard procedure at 24 hr post mortem.

CONCLUSION

ELV stimulation for 40s duration with either system in a nose-shackle configuration does not consistently result in tender LD muscles in the commercial operations studied, even though the animals are less than two years old, and stimulation is performed within four minutes of slaughter.

The use of an earth electrode contacting the anus or leg region (see Appendix) increased the current flow, resulting in more consistent meat tenderness. When animals with an ultimate LD pH of 5.9, or greater, were excluded, 95% of LD muscles were acceptably tender. Current flow could be increased by increasing stimulation voltages up to 80-85V, which which is the level used overseas. In Australia, where peak voltages for ELV are limited to 45V, the results indicate that the high resistance in the upper leg and shackle must be bypassed to allow effective electrical stimulation to occur.

ELV stimulation for 40s with either of the commercial units used in this work in a nostril-leg configuration produced beef with a tenderness quality at 24 hr equivalent to that of the tenderstretch process.

The insertion of the nostril electrode into alternative sites such as the stick wound and the tip of the nose was totally ineffective, even though there was a good visual contraction of the carcass.

Carcass contraction in response to ES is no indication of effective stimulation.

Modifications to the shackle chain to improve the contact at the hock were also ineffective in improving the performance of the nostril-shackle configuration.

The manufacturer's recommendation of operating the Koch-Britton equipment for 40s duration in the 3s on / 1s off cycle (10 major contractions and relaxations) was modified to a very rapid cycle of 60 ms on / 20 ms off. This rapid cycle had only one major contraction and relaxation, was not nearly as severe on the structural members in the bleeding/stimulation area, and improved worker safety in the area. The 8 to 10% additional blood collected when the KB unit is used in the 3s on / 1s off cycle is still obtained with the rapid cycle.

RECOMMENDATIONS

1. A rubbing bar electrode at ground or at a floating potential should be installed to contact carcasses between the pinbone and the stifle joint of the shackled leg.

2. The nostril electrode should be inserted into a nostril, in the direction of the brain, to a depth of at least 120 mm and remain secured there for the duration of the stimulation.

3. An easy to read ammeter (maximum full-scale deflection of 1 amp) should be installed with all ELV systems and be calibrated to read the peak current value of the pulsed supply to the carcass. The minimum accuracy of the meters should be ±2.5% of full-scale deflection.

ACKNOWLEDGMENTS

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APPENDIX

RUBBING BAR ELECTRODE FOR EFFECTIVE ELECTRICAL STIMULATION WITH ELV UNITS USING THE NOSE TO SHACKLE CONFIGURATION

Carcasses undergoing stimulation must not be in physical contact with other carcasses.

The earthed rubbing bar electrode should be made adjustable for fine tuning to the needs of the establishment.

For Works with a Powered Rail in the Stimulator Area

An earthed, fixed rubbing bar electrode (Fig.1) would be suitable in a works where the carcass stimulation position is on a powered chain. A fixed bar can be supported from either the overhead rail support structure or any adjacent structure (e.g. nearby wall columns).

The rubbing bar electrode requires a lead-in section to ensure the carcasses are located correctly and a stimulation section positioned to ensure the best location for contact on the carcasses.

The initial part of the lead-in section should be at a height of 2.5-3m below the rail and angle into a position directly below and parallel with the rail. In this position the moving carcass should rotate so that the bar rubs on the flank of the hindlegs between the pinbone and the stifle joint. The bar should then rise to a height approximately 1.8-2m below the rail and still be directly beneath it. In doing so the free leg will be lifted up above the rubbing electrode. The flank of the carcass will probably face the bar with the upper part of the rear leg contacting it during stimulation. The length of the electrode must be sufficient to ensure the carcass is in contact with the electrode for the required period of stimulation.

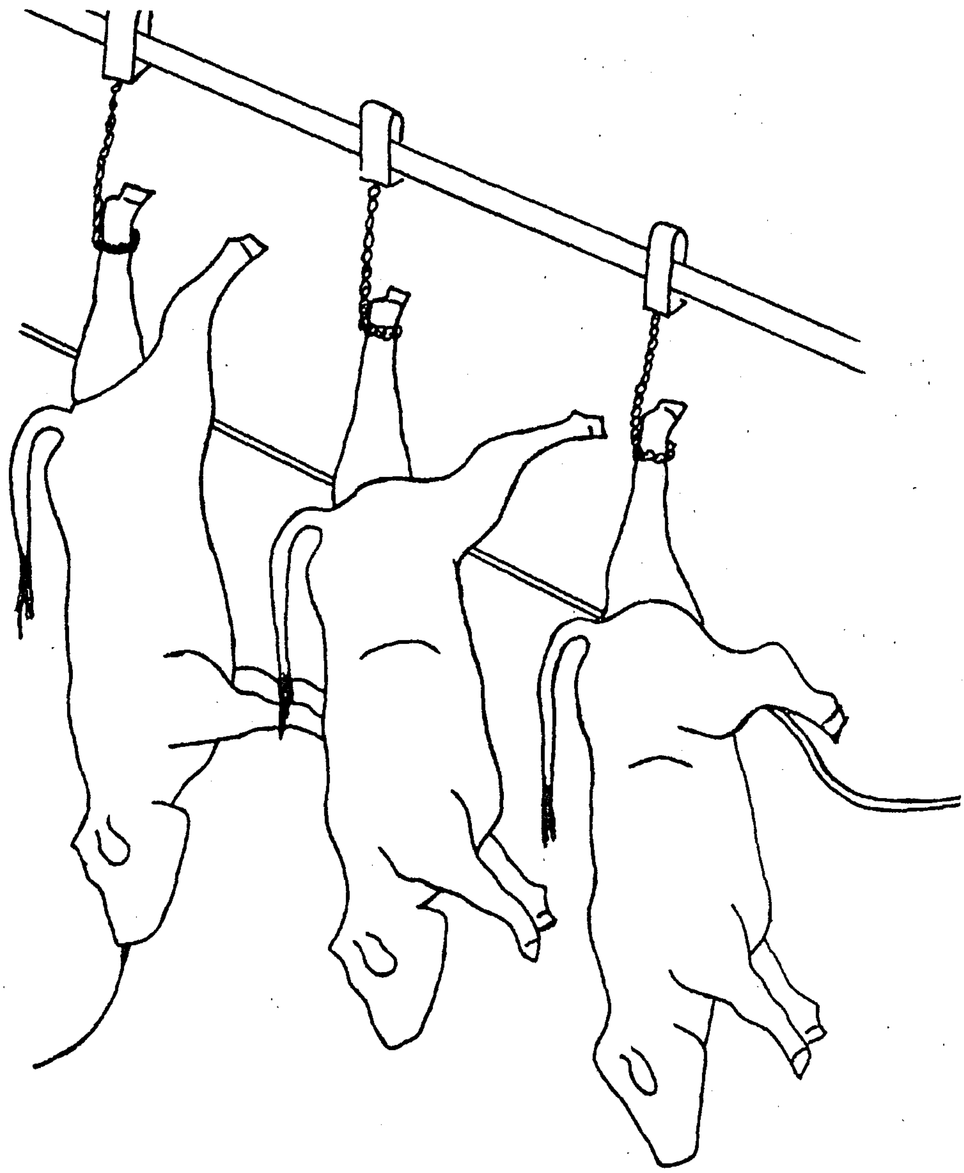

Figure 1: Suggested rubbing bar electrode for those works which have a powered rail in the stimulator position.

For Works with a Gravity Rail in the Stimulator Area

For plants which do not have powered rails, an earthed rubbing bar electrode that retracts to a position away from the rail may be necessary. With the carcass stationary at the stimulation position, the bar electrode (driven by a ram) should be activated (momentarily after stimulation is applied) to move into a position approximately 1.8-2m below rail height and directly beneath the rail (Fig.2). On completion of stimulation, the electrode should be retracted to allow the carcass to move forward and for the next carcass to enter.

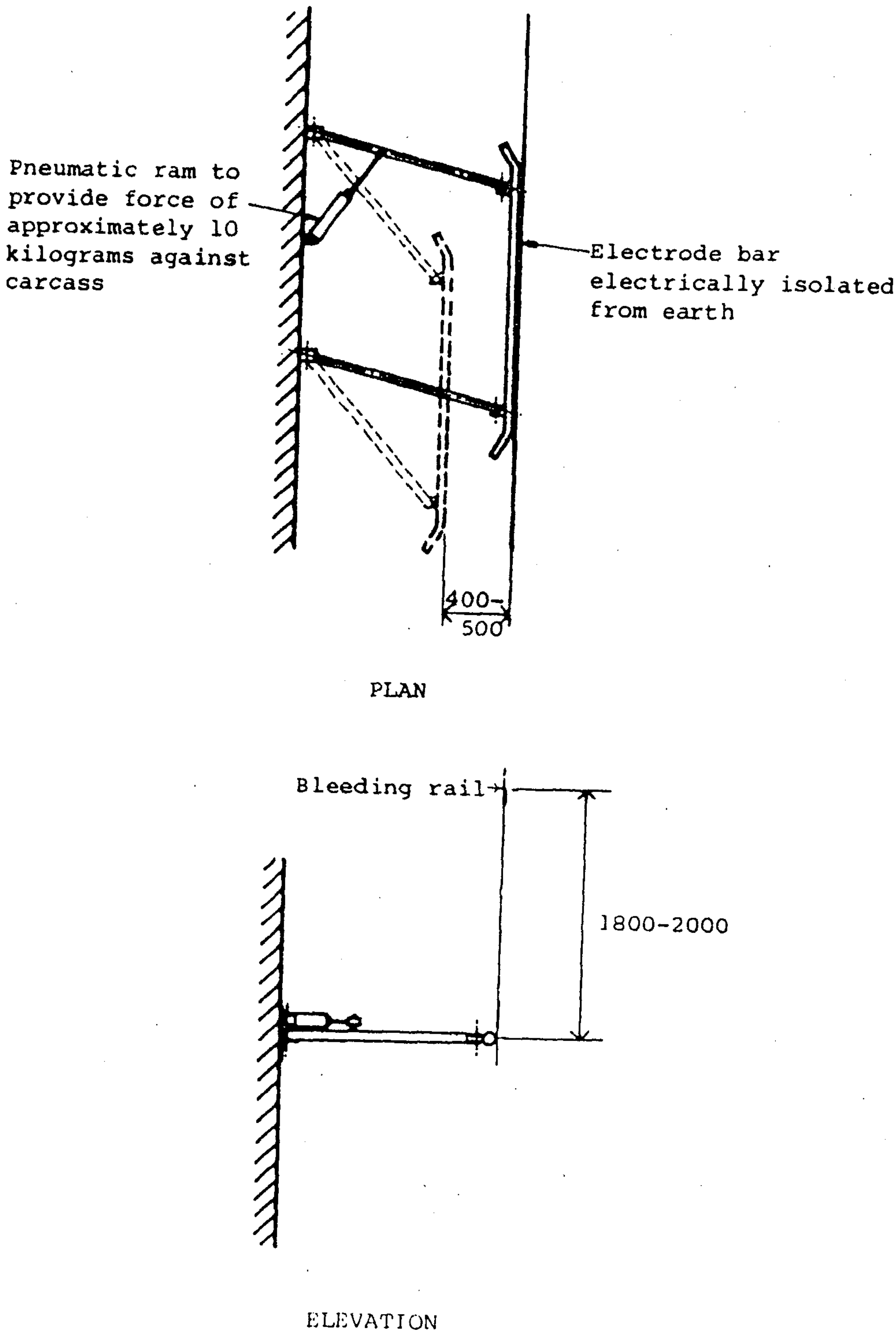

Figure 2: Suggested earth bar for ELV ES on gravity bleed rail.

TABLE 1: Warner-Bratzler initial yield shear force measurements obtained for SM, LD, GM and BF muscles, from steers (0-2 tooth) either stimulated with Koch-Britton nose/shackle system or not stimulated.

	Treatment						
	Non-stimulated[a]		Stimulated[b]				
Muscle	CAT	CTS	A/F	A/S	B/F	B/S	LSD[c]
SM	16.78	5.64	7.09	7.76	7.33	8.24	2.26
LD	11.30	6.02	6.46	7.70	6.32	7.88	2.53
GM	6.20	3.34	4.26	3.90	4.74	3.74	1.19
BF	6.22	5.06	4.86	4.49	4.84	4.00	1.60

[a] CAT - non-stimulated sides hung via Achilles tendon;
CTS - non-stimulated sides hung by sacrosciatic ligament.

[b] Stimulation using ES in time modes A (60s: 2s on/1s off) and B (40s: 3s on/1s off). S = shackled leg and F = free leg.

[c] Least significant difference at P<0.05.

[a] CAT - non-stimulated sides hung via Achilles tendon;
CTS - non-stimulated sides hung by sacrosciatic ligament.

[b] Stimulation using ES in time modes A (60s: 2s on/ 1s off) and B (40s: 3s on/ 1s off). S = shackled leg, F = free leg.

[c] Least significant difference at P<0.05.

TABLE 2: Warner-Bratzler initial yield shear force measurements obtained for pre-rigor DP and ST muscles from steers (0-2 tooth) either stimulated with Koch-Britton nose/shackle system or not stimulated.

	Treatment						
	Non-stimulated[a]		Stimulated[b]				
Muscle	CAT	CTS	A/F	A/S	B/F	B/S	LSD[c]
DP	12.84	(6.48)	(6.00)	8.46	(6.66)	6.68	2.62
ST	14.78	(4.64)	4.58	4.74	4.34	4.82	1.38

[a] Value in parentheses are for muscles removed post-rigor. See text for details.

[b] CAT, CTS: non-stimulated carcasses were hung from the Achilles tendon (CAT) and from the sacrosciatic ligament (CTS) respectively.

[c] Stimulation using ES in time modes A (60s: 2s on/1s off) and B (40s: 3s on/1s off).

[d] Least significant difference at P<0.05

[a] Value in parentheses are for muscles removed post-rigor. See text for details.

[b] CAT, CTS: non-stimulated carcasses were hung from the Achilles tendon (CAT) and from the sacrosciatic ligament (CTS) respectively.

[c] Stimulation using ES in time modes A (60s: 2s on/ 1s off) and B (40s: 3s on/ 1s off).

[d] Least significant difference at P<0.05.

TABLE 3: Warner-Bratzler initial yield shear force and pH values for LD samples removed two or 24 hours post-slaughter from non-stimulated carcasses or carcasses stimulated with the Koch-Britton or AIS systems for 40s in a nostril-shackle/rail earth configuration or with the AIS system for 40s, 60s or 80s using an additional pathway to earth.

Means with the same superscript in any one row are not significantly different ($P<0.05$).

Parameter	Time post-slaughter	TREATMENT Non-stimulated	AIS shackle/earth	Koch-Britton shackle/earth	AIS with anal earth			AIS with rump earth		
Stim. time (s)	-	-	40	40	40	60	80	40	60	80
WB initial yield force (kg)	2	14.6^{a}	12.9^{a}	11.6^{b}	8.6^{c}	8.5^{c}	7.8^{cd}	10.6^{b}	$9.0b^{c}$	7.0^{d}
	24	9.6^{a}	7.3^{b}	6^{b}	4.8^{c}	3.3^{d}	4.0^{cd}	$4.0c^{d}$	4.5^{c}	4.3^{c}
pH 2 hr	2	6.68^{a}	6.12^{b}	6.17b	5.65c	5.84^{cd}	5.82^{cd}	5.96^{d}	5.77^{c}	5.74^{c}
pH 24 hr	24	5.54^{a}	5.57^{a}	5.62^{a}	5.59^{a}	5.61^{a}	5.59^{a}	5.63^{a}	5.52^{a}	5.51^{a}

TABLE 4: Warner-Bratzler initial yield shear force and pH values for LD sample removed two and 24 hours post-slaughter from non-stimulated carcasses stimulated with the Koch-Britton system (40s).

Parameter	Time post-slaughter (hr)	(a) Non-stimulated	(b) Normal nostril shackle	(c) Nose electrode in tip of nose	(d) Nose electrode in stick wound	(e) Shackle electrode with modified chain	Nostril-anal earth *
WB initial yield force (kg)	2	15.1^{a}	12.9^{b}	16.2^{a}	14.1^{a}	13.4^{ab}	8.7^{c}
	24	9.6^{a}	7.7^{b}	9.1^{a}	9.8^{a}	8.6^{ab}	4.9^{c}
pH 2hr	2	7.0^{a}	5.8^{b}	6.6^{a}	6.7^{a}	5.8^{b}	5.8^{b}
pH 24hr	24	5.6^{a}	5.6^{b}	5.6^{a}	5.5^{a}	5.6^{b}	

Means with the same superscript in row not statistically different.

* Results from experiments 4 & 5.

TABLE 5: Warner-Bratzler initial yield shear force and pH values for LD^{+} and ST^{++} samples removed two hours and 24 hours post-slaughter from non-stimulated carcasses or carcasses stimulated with the Koch-Britton in a number of time modes

Parameter	Muscle	Time post slaughter	Non-stimulated	Nostril shackle 3s on 1s off	Nostril shackle 60ms on 20ms off	Nostril leg 60ms on 20ms off	Nostril shackle continuous for 30s (no cycle)	Nostril shackle continuous for 40s (no cycle)
WB initial yield	LD^{+}	2	13.9^{a}	12.5^{a}	12.7^{a}	9.8^{b}	-	-
force (kg)	LD	24	9.2^{a}	7.0^{b}	7.2^{b}	5.2^{c}	-	-
pH 2hr	LD	2	6.7^{a}	6.1^{b}	6.1^{b}	5.9^{b}	-	-
pH 24hr	LD	24	5.6^{a}	5.6^{a}	5.7^{a}	5.6^{a}	-	-
WB initial yield force (kg)	ST^{++}	1	13.7^{a}	9.8^{b}	-	-	9.2^{b}	6.2^{c}
pH 1hr	ST	1	6.7^{a}	6.1^{b}	-	-	6.0^{b}	5.8^{b}
pH 24hr	ST	24	5.7^{a}	5.5^{a}	-	-	5.6^{a}	5.5^{a}

Means with the same superscript in a row not significantly different.