Reassessing the principles of electrical stimulation
revisiting conventions & exploring new opportunities

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Electrical Stimulation & the NZ story

- AC & A
- History
- Cost
- Why re-litigated; animals change, markets change, processing efficiencies tighten, customer requirements shift
The conventions surrounding ES

- *Used to prevent CS*……maybe originally, but is CS really a commercial problem these days?
- *Stimulation improves tenderness due to supercontraction of myofibrils*…. Questionable
- *Stimulation always improves tenderness*….. In many cases, but can also significantly compromise it
- You can only use low voltage stimulation if it’s applied within 5 minutes of slaughter… No
- *Only two options – high voltage or low voltage*…. no, now a whole range of possibilities available. In all probability, the options are probably limitless
The cold shortening continuum

Adapted from Locker & Hagyard, 1967 & Davey & Gilbert, 1974
Effect of muscle length on tenderness

Derived from Davey & Gilbert 1967
Shearforce after 21 days of ageing in beef (LD)

Shear Force (N)

- No stimulation
- Stimulation

pH of sample at transfer from 35°C to 0°C
Commercial conditions required to cold shortening beef (LD)

150 kg beef side chilled at -5 deg at 5 m/s air speed
Commercial conditions required to cold shortening lamb

20 kg lamb carcass chilled at 0 deg at 1 m/s air speed
Contrasting rates of tenderisation in beef LD using different process options

Fast rigor – Electrical HO stun, Low Voltage/low frequency immobilisation, HVS, 8 deg 8 hours to 0 deg
Slow rigor – Captive bolt stun, no electrical inputs, 4 deg for 12 hours to 0 deg
Defining characteristic of cold shortened meat

1. Final toughness is substantially increased
2. The cold shortened toughness does not age out
3. Some level of shortening is inevitable and will increase initial toughness, but doesn’t affect final tenderness – this should not be viewed as cold shortening
4. Generating cold shortening commercially in carcasses is difficult
5. Many examples of cold shortening may well be, reduced ageing rate due to rapid temperature decline
Convention 2: Stimulation improves tenderness due to direct effect on muscle

- Supercontractions produce visible disruption of myofibril that may lead to tenderisation (Marsh, 1986; Takahashi et al, 1987; Ho et al, 1996)
  - 60Hz stim produced supercontraction
  - 2Hz did not
Can specific stimulation parameters affect tenderness directly?

- Stimulation that produces tenderisation without substantial pH decline has the potential to provide significant commercial opportunities.
- Higher frequency (e.g. 50-60 Hz) produce higher peak Ca\(^{2+}\) and therefore higher peak forces and supposedly supercontraction.
- Muscle extension during contraction (eccentric) triggers muscle damage in vivo.
This is an eccentric contraction!
Effect of different stimulation frequencies and carcass posture during stimulation on shearforce of lamb LD

Shearforce measured at 24 hours post mortem
Surely isn’t it simply that stimulation simply works via the acceleration in pH fall

- Electrical stimulation accelerates pH fall – that is all it does
- Rigor is attained sooner
- Ageing starts at (or around) rigor
- So ageing begins earlier when carcass temp is high and gets a headstart
Calculated tenderness – taken from Dransfield (of course!)

Dransfield, Jones & Macfie, 19??
Evidence to support ES effects are due to pH/temp

Aged at 15°C
Convention 3: *Stimulation always improves tenderness*
Heat toughening - is it sarcomere length dependent?

Adapted from Locker & Hagyard, 1967 & Davey & Gilbert, 1974
It seems all muscle shortenings are not equal

- Cold shortening – *increased* initial toughness; reduced tenderisation capacity resulting in high ultimate toughness
- Heat shortening – *some* initial tenderness; but reduced tenderisation capacity
Heat toughening can be produced post rigor

<table>
<thead>
<tr>
<th>Pre-rigor</th>
<th>Post-rigor</th>
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<tr>
<td>15°C</td>
<td>37°C</td>
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Rigor mortis

Ultimate tenderness

![Graph showing shear force (in Newtons) against ageing (in days) for heat-toughened and not heat-toughened samples.](image)

Thomson et al, 2008
Heat toughening - is it proteolysis dependent?

Ultimate shearforce: effect of high temperature incubation at rigor

- **Shear force (N)**
- **Time at high temperature (hours)**
- **Temperature:**
  - 35 C
  - 40 C
It’s not just tenderness

- Problems are not just tenderness but also typically high drip and poor colour – PSE!
Summary so far:

- In theory, you can cold shorten but would you, or could you, commercially?
- Muscle damage probably does occur with some electrical stimulation but it’s not clear if it consistently affects tenderness?
- We support, quite simply, the pH/temp modification story
- You can over-stimulate and produce poor quality – electrical stimulation is not the panacea for meat quality
- Changing temp profiles of carcass is difficult whereas changing pH decline is relatively simple … and this just got easier with new options for stimulation parameters!
Convention 4: *low voltage stim only within 5 mins of slaughter – needs nervous system*

- Low voltage stimulation produces strong muscle contractions immediately after slaughter.
- Neuromuscular block abolishes responses to low voltage stimulation.
- Therefore – the nervous system is needed for low voltage stimulation.
Measuring force of muscle contraction through muscle pressure

- Amplifier
- Pressure transducer
- Flexible catheter
- Digital storage
- Low flow, high pressure pump
Threshold responses to stimulation in neuromuscular blocked sheep carcasses

[Graph showing the relationship between current needed to elicit a response (mA) and minutes post slaughter.]
Convention 5: the only choices are high and low voltage
The Standard (NZS6116:2006) introduces three levels of risk associated with electrical equipment:

- Operator safe (Class A)
- Touch safe but unsafe to work on (Class B)
- Unsafe for contact under any circumstances (Class C)

Allow any combination of pulse characteristics to be assessed for safety.
New generation electrical processing technologies

- Pulse interval (1/Hz)
- Pulse (peak) amplitude
- Pulse duration
Alternative voltages and waveforms are possible

- **High voltage**
- **Intermediate Voltage**
- **Low voltage**

![Graph showing voltage levels and waveforms with 15 Pulses / second](image-url)
In theory, options limitless. So how do you define parameters?
Effect of pulse width and pulse amplitude on the force of muscle contraction

![Graph showing the effect of pulse width and pulse amplitude on muscle response.](image-url)
Effect of stimulation duration on threshold response

![Graph showing the effect of stimulation duration on threshold response. The graph plots pulse width on the x-axis and current (mA) on the y-axis. There are two lines: one representing 'After 10 secs of stim' and the other 'After 30 secs of stim'.]
Effect of stimulation frequency on muscle contraction

![Graph showing the effect of stimulation frequency on muscle contraction]

- 50Hz
- 15Hz
- 3Hz

% maximal contraction vs. Time (seconds)
Summary:

- Demonstrates that between 10 to 20 Hz is optimal for a pH decline - we knew that from old data
- 50 Hz gets good response but membrane becomes unresponsive before max pH decline. Intermittent pulsing to allow membrane recovery eg. USA – 1 sec on, 1 sec off avoids this
- Low frequency – can get equivalent effect but takes much longer eg. 5 Hz
- At same frequency you can have very different pulse widths – fat pulses thin pulses. Allows tailoring for immobilisation (nerves), stimulation (muscle), safety
Commercial applications

Electrical inputs are used for purposes other than managing meat quality

- Electrical stun
- Immobilisation
- Back stiffener
- Stimulation
- Welfare
- Halal compliance
- Worker safety
- Carcass stimulation
- Carcass damage
- Localised stimulation
- Accelerate
- Tenderisation
Cattle immobilisation video
Lamb immobilisation video
Commercial applications: Optimal frequencies for various processing technologies

Richards, 2006
Processing options

defining the optimal processing environment for different market requirements

"Processing Space"

Increasing chilling rate

Increasing stimulation

PSE

Fast rigor process

Slow rigor process

Cold

Short
Summary: Opportunities for new electrical technologies

- Developing a much wider range of options, using waveforms designed for specified applications
- Developing systems to produce more consistent and precise pH changes
- Tailor the electrical inputs on a carcass by carcass basis.
Examples of two contrasting processes

Fast Rigor

Slow Rigor

Electrical stimulation/Slow chilling

Rapid tenderisation
Potentially some loss of final tenderness
Increase purge
Good initial colour but reduced colour stability

No stimulation/Rapid chilling

Slow tenderisation
Achieves good final tenderness
Minimal purge
Good colour stability
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