MEAT TECHNOLOGY UPDATE
Cutting edge technology for the meat processing industry

Meat technology update

1/06 – February 2006

Electrical inputs during beef processing

During slaughter and dressing, beef carcases may be subjected to a range of electrical inputs. These are used to: limit the danger to slaughterers from kicking; assist rapid bleeding; prevent broken backs from hide pulling; and optimise meat quality. Each of these applications may require a specific current, waveform and frequency. Use of incorrect electrical parameters may result in damage to the carcase, poor meat quality and safety risks.

Devices that apply electrical inputs at various points on the slaughter floor are used extensively by Australian processors. Research, funded by Meat & Livestock Australia, has been undertaken over the last few years to develop electrical parameters best suited to each application. A suite of equipment utilising this new generation electronic technology has been developed. This Meat Technology Update provides guidelines on the correct application of electrical currents during beef processing.

The effect of different electrical parameters

For many years, electrical inputs during beef dressing were limited to electrical stimulation (either extra low voltage or high voltage) to limit toughening and downward hide puller back stiffening to prevent broken backs. Back stiffening used the standard 50 Hz mains frequency, and electrical stimulation (ES) used frequencies of about 14 Hz or 40 Hz. The frequency for ES was selected to provide the greatest utilisation of energy from the carcase and hence the most rapid onset of rigor and reduction in muscle pH to prevent cold shortening. While the consequence of inadequate electrical input was long recognised, the consequences of excessive ES were not.

For some heavy, and therefore, fat carcases, the application of any ES leads to too rapid a fall in pH. In some cases the pH was found to be at or below pH 6 by the time the carcase entered the side chiller. This increases the chances of meat quality problems due to toughness from heat shortening and meat colour issues.

The effect of ES on rate of pH fall is related to the pulse frequency (Figure 1). At a frequency of 10–20 Hz the effect on rate of pH reduction is maximal and gradually drops off as the frequency increases. At about 2,000 Hz, the effect on pH decline is minimal; therefore, a high frequency is more suited to applications such as immobilisation, when further stimulus to the rate of pH fall is not required as it would interfere with a later, controlled ES.

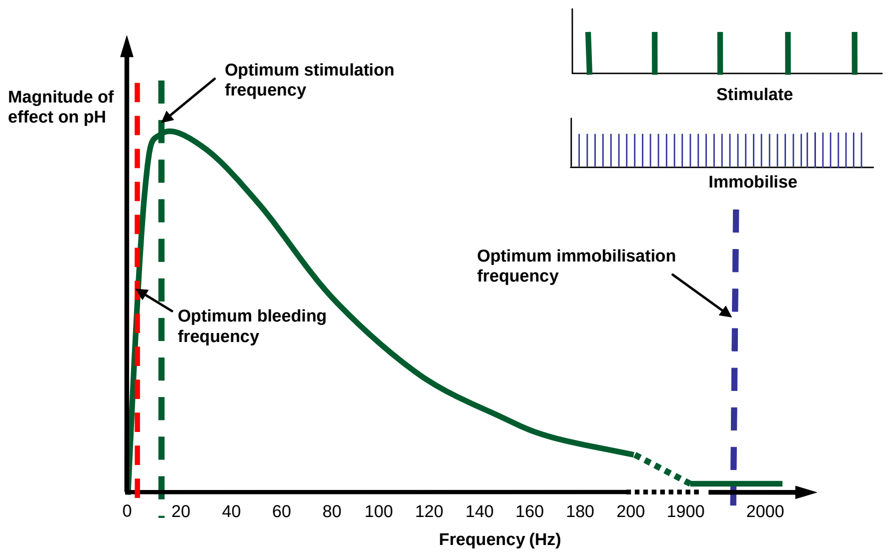

Figure 1: Effect of frequency on rate of pH fall

Principles

Electronic equipment has been developed to generate electrical outputs that are optimal for specific applications and to control electrical stimulation equipment. All the new generation systems consist of several basic modules (Figure 2) to provide a safe, controlled current to the carcase. The heart of the system is a processor and memory, which can store multiple parameters which are switch selectable. Each system can be programmed to suit the individual application.

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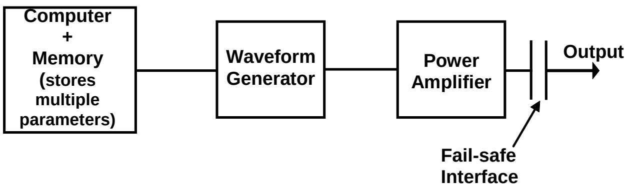

Figure 2: Basic modules of electrical systems for slaughter floors

All systems provide a constant current output. This is achieved by sending a small 'measurement' pulse prior to the main 'stimulation' pulse. Feedback from this pulse, allows the voltage of each main pulse to be adjusted to provide a constant current (Figure 3).

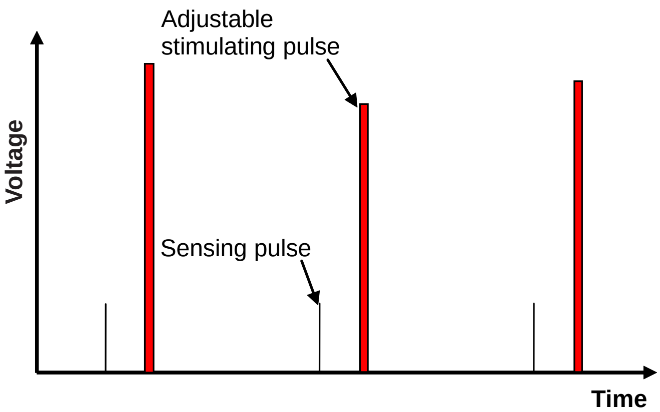

Figure 3: Basic pulse arrangement

Immobilisation

Immobilisation of the carcase in the landing area after stunning is done to limit the risk of injury to slaughterers. It can also streamline production as the stationary leg is easier to shackle for hoisting. Immobilisation currents can be applied on a landing cradle (Figure 4) or a bleeding table.

The recommended immobilisation system utilises a constant current system—at a frequency of 2,000 Hz, current 1–2 A and pulse width of 100 µs—applied for 7 to 15 seconds. This acts through the animal's nervous system and presents the carcase in a motionless state. There is little effect on muscle pH, allowing ES systems to be applied later in the process to produce the optimum rate of pH reduction.

Electronic bleeding

Ever since ES was first introduced, it has been noted that additional blood is released at that location. Experiments to determine the effect of different electrical parameters indicated that at least an extra 1 kg of blood per head could be obtained when the treatment was applied in the blood drain about 2 minutes after sticking (Table 1). Pulse frequencies of 5 Hz and 14 Hz for 35 seconds gave similar results, with a higher yield obtained with 500 mA compared with 300 mA.

A frequency of 5 Hz has less effect on muscle pH and is recommended for situations where heavy carcases are processed. Where ES is required to prevent cold shortening, the higher rate of 14 Hz is recommended. The current can be applied in the bleeding area using fixed rubbing bars. Meat Technology Update 4/03 provides additional details.

Figure 4: Beef landing cradle

Table 1: Effect of ES on blood yield

Group	Frequency (Hz)	Peak current (mA)	Blood weight perhead (kg)
I	14	300	1.5
II	14	500	1.8
III	Control		0.6
IV	5	300	1.5
V	5	500	1.9

Electrical stimulation

Muscles of the live animal have a supply of glycogen from which they derive their energy. After death, glycogen breakdown continues and lactic acid now accumulates, resulting in a reduction of the muscle pH from around 7.0 in the live animal to an ultimate value of about 5.5 in normal muscle after rigor mortis.

If the muscle cools rapidly before it has entered rigor (pH 6), the meat may be tough due to cold shortening. The solution has been to apply electrical stimulation to the carcase, either using extra low voltage systems at bleeding or high voltage (1,100 V peak) after hide removal, or on dressed sides.

The stimulation of the muscles accelerates the breakdown of glycogen which hastens the onset of rigor. Decline in pH can be used as a measure of how much the ageing process has been accelerated. Under the MSA temperature/pH 'window', optimum ageing and meat quality is achieved when the muscle reaches pH 6 between 35°C and 12°C.

Using the earlier ES systems, it was not possible to guarantee that each individual animal received the optimum amount of stimulation to achieve the required rate of pH decline. The latest systems have overcome this by:

- segmenting the system so that each carcase can be monitored individually;
- using feedback from monitoring to adjust the dosage for that carcase;
- utilising waveforms with narrow pulse widths, which allow use of higher currents that still remain safe;
- measuring the carcase resistance using small test pulses and using the feedback to control the dosage.

Carcases can be stimulated either through the nervous system or by direct stimulation of the muscle. The nervous system of a slaughtered animal decays slowly such that by about 40 minutes after death, the nervous system can no longer be utilised.

Pre-dressing stimulation

When ES is applied soon after slaughter, such as in the bleeding area, the nervous system can be stimulated using quite low voltages. Systems were originally extra low voltage (ELVS), but more common now are systems that apply a short pulse width waveform referred to as low voltage electrical stimulation (LVES). This can be combined with electronic bleeding at a frequency in the range 5 to 20 Hz at a current of up to 1 amp. The lower pulse rate will result in good blood recovery without rapid pH decline and is best for heavier carcases where ES may contribute to heat shortening and meat colour problems.

The current can be applied by rubbing bars contacting the butt and shoulder areas of the carcase. Most beef ES systems currently operate pre-dressing because:

- extra blood is released before dressing begins;
- space is generally available in this area; and
- it eliminates nervous responses.

Post-dressing stimulation

The extra low voltage systems were found to be ineffective when applied later in the dressing process and in the 1970s high voltage (to 1100 V peak) systems were developed. When new-generation ES is applied later in the dressing process, wider pulse widths are required than if it is applied pre-dressing because the nerves are no longer as responsive. The r.m.s. voltages are still in the relatively safe zone even with the wider pulses. This is referred to as mid voltage electrical stimulation (MVES).

This is applied to beef sides using rubbing bars similar to the earlier high voltage systems, but without the need for elaborate safety precautions.

Elimination of kicking

When a knife incision is made during the early stages of dressing carcases, a kicking response often results, especially at the first legging station. This can be dangerous for the operator, possibly resulting in bruising and knife wounds. This nervous response can be eliminated by applying an electrical input to the carcase prior to the legging stands. Where acceleration of pH decline is not wanted, high frequency (2,000 Hz) ES applied for 20–30 seconds at a constant current of 1000 to 2000 mA (c.f. immobilisation) will eliminate this response. Alternatively, normal pre-dressing ES can be utilised if an increase in the rate of pH fall is needed.

The current can be applied in the bleeding area using rubbing bars.

Back stiffening

The large forces involved with beef downward hide pullers place severe strain on the vertebrae of the carcase while pulling over the shoulders and head. This can be sufficient to part the vertebrae and sometimes damage the muscle. Breaks in the back have been largely overcome by applying an electric current to the back of the carcase to contract the muscles and support the spine.

In order to get sufficient energy into the back muscles for adequate contraction, large AC voltages (typically 180 V rms, 50 Hz) have been applied over the vulnerable loin area through spikes penetrating the muscles. Currents in the order of 3 A are typically applied to get adequate contraction.

Safety is a major problem with these systems, as potentially lethal voltages are applied to the carcase adjacent to where operators are working. Most installations use an isolated system but should a failure in the wiring occur in which one side of the wiring shorts to ground, the whole carcase will be live with respect to ground, resulting in operators being exposed to a potentially dangerous situation.

The new electronic back stiffener uses a waveform that is more energy efficient than the mains-derived AC voltage, allowing it to be applied with contact plates rather than penetrating spikes. This reduces potential contamination problems.

When subjected to the calculations presented in AS/NZS 60479.2:2002, 'Effects of current on human beings and livestock – Part 2: Special aspects', the electrical output of the electronic back stiffener is regarded as 'unlikely to cause ventricular fibrillation'.

The effectiveness of the current needed to contract the muscle is related to the duration, frequency and magnitude of the pulse. The magnitude of the pulse has a more significant effect than the duration. The very large amplitude, short duration pulses from the electronic system contract the back muscle of the carcase at a considerably lower and, therefore, safer energy level than traditional sine wave systems.

The stiffening effect increases with the pulse rate (or frequency), but has an upper limit. Maximum stiffening occurs at between approximately 40 and 100 Hz. Application of current at these frequencies can also have a significant effect on rate of pH decline, which may not always be desirable. As the frequency increases above 100 Hz, the stiffening effect declines. The electronic back stiffener operates at 40 Hz, which gives sufficient stiffening; the effect on muscle pH is minimised by adjusting the electrical energy to the minimum required and limiting the time of application.

The back stiffener operates at a constant energy by automatically adjusting the applied voltage to compensate for the variable contact resistance. This results in a controlled dose and more uniform level of muscle stimulation than would be achieved with a simple transformer operating at a constant voltage.

Safety

A major feature of this new generation electrical stimulation equipment is its safety. The waveforms are designed to conform to a new draft Australian/New Zealand standard on meat industry electrical safety that is under preparation. Another safety feature built into the electronics is its ability to detect the difference between a beef carcase and a human (beef carcases have a much lower contact resistance than humans; however, sheep carcases do not). If set properly the units will not turn on to full power if a person inadvertently or purposely touches both bars while no carcase is contacting the electrodes.

Summary

Special wave forms, pulse frequencies and currents have been developed and assessed for efficacy and safety for each application. These are summarised in Table 2. The use of certain electrical parameters in a situation for which they have not been tested or approved could potentially lead to both a reduction in meat quality and an electrically unsafe situation.

Table 2: Electrical parameters for each application

Application	Frequency (Hz)	Pulse width (µs)	Peak current (mA)
Immobilisation	2000	100	1000–2000
Bleeding	5	500	300–500
Elimination of kicking	2000	150	1000–2000
LVES	14	500	300–500
MVES	14	1000	400–800
Back stiffening	40	2000	2000–5000

Contact us for additional information

Meat Industry Services is supported by the Australian Meat Processor Corporation (AMPC) and Meat & Livestock Australia (MLA).

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