final report

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Assessment of Commercial Requirements for Smartstim in Sheepmeat Processing

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ABSTRACT

The SmartStim was installed in July 2010 with the feedback system set up and calibrated in November 2010. Site visits were also undertaken in February and April 2011 to check system functionality, make any necessary modifications and evaluate meat quality performance. An additional visit was undertaken recently and the opportunity to further validate the meat quality outcomes was included.

Routine monitoring using the remote access has been carried out several times per week and generally on a daily basis. Software upgrades and system maintenance have been implemented through the remote access and a summary of this is provided below. Generally this has worked very satisfactorily apart from odd occasions when log-in has not been possible due to maintenance of the processor's IT system that precluded external access.

An additional site visit was conducted in January 2012 and meat quality validation carried out.

1. System performance – meat quality

- The pH fall is generally consistent and the target pH has been set up to ensure that the requirements of the MSA pH/temperature window are achieved.

- The tenderness is highly acceptable after a 3-day maturation period, producing an average of 4.2 kgF and this converts to a 'very tender' category as rated by consumers. The process produced minimal variation between samples (standard deviation 0.9 kgF), and the majority of samples scored a 4* or 5* when the shear force values are converted into MSA scores.

- Drip loss of the boneless shortloins is acceptable, with an average of 1.2%.

- Overall the meat quality has been consistent since installation of the technology in July 2010. However the most recent system optimisations have improved the meat quality outputs further and all are better than the industry average from the Carne Technologies commercial database.

2. System performance – remote monitoring

The SmartStim has been monitored by Carne on a weekly basis (typically daily) using the remote access system. Key observations are as follows:

- Generally the carcass responses to the stimulation, as monitored by the load cell segments, conformed to expectations. At times, the traces become irregular but these events seem to be linked to multiple carcasses on one hook (see below).

- The plant clears the detain rail at regular intervals by loading typically between 2-3 carcasses onto 1 hook. While this is clearly unavoidable given the current chain configuration, this prevents the feedback system from operating and the pH control is lost.

While these carcasses receive stimulation, the overall level of stimulation is reduced and, generally, the pH of these carcasses is higher after stimulation than those that are on individual hooks.

- A further consequence of this is that the SmartStim carcass number tracking gets out of sequence. While this currently does not affect the performance of the system, if in time the plant wish to use the calculated pH's from the system as part of the MSA auditing routine, this would have to be resolved.

- The visit in January 2012 provided an opportunity to check the overall performance of the system. Carcass responses to the stimulation system, the pH declines and the meat quality outcomes were assessed.

Executive summary

This project involved the development and installation of a Smart Stimulation (ie. SmartStim technology) commercial prototype configuration and evaluation of the technology at a sheepmeat processing plant. This pre-commercial installation enabled:

1. on-going evaluation of the performance and associated benefits of SmartStim in sheepmeat processing;

2. determination of the optimal installation and service package for the commercial rollout;

3. an assessment of integration and interfacing of the components of SmartStim, including the Merit Of Measurement electronics; and

4. evaluation of the level and responsiveness of service provided by Carne Technologies (assessed by independent CSIRO) during and after installation, and during ongoing maintenance of the remote data capture and ongoing reprogramming

Unlike Generation One meat electronics, SmartStim requires a far higher level of meat science understanding than that found in MSA methodology. Consequently, maximum benefit from SmartStim can only be obtained using a combination of specialised meat science know-how and processor understanding in some form of service package bundled with the sale of the SmartStim hardware.

The ongoing success of this project depends on the commitment of the sheepmeat processor to ensure that SmartStim is maintained, serviced and operated optimally. Therefore, this project requires that the processor assign a 'champion' who will assume responsibility for SmartStim during the current project and beyond the trial period. This person will learn all operational aspects of the technology during the installation and early trailing phases. An operational manual would be developed by the processor's SmartStim operative specifically for the process. In addition, this person will be the primary point of contact for the service providers and MLA during and after the installation.

There will also be a requirement for the processor to provide QA and technical resources to assist with the initial primary validation (over 1 week after installation, estimated between mid-December 2009 and mid-January 2010), then during the extensive ongoing testing (over 6 months). Specifically QA and MSA graders will be required to conduct routine pH declines and co-ordinate results with the contractor, Carne Technologies. Carne Technologies will develop remote data capture function, and the processor may be required to provide some IT support if required to enhance that data upload (ie web-based). Once commissioned and operating procedures approved by the processor, it is a requirement of the processor to operate the system continuously as part of normal processing.

Contents

Introduction and Purpose

1.1 Background

Electrical stimulation
In the 1980's, the New Zealand meat industry pioneered the use of electrical stimulation of carcasses to overcome toughness associated with cold-shortening. However, in reality the main application of electrical stimulation is to accelerate the rate of tenderisation. The process involves a putting an electrical current through the carcass or sides after slaughter. This process causes the muscles of the carcass to contract and speeds up the onset of rigor mortis. Rigor mortis is the condition that occurs several hours after slaughter when the carcase is rigid and the muscles are relatively hard. The meat enzymes that cause the meat to become tender are only activated once the meat is in rigor mortis and, therefore, the earlier rigor mortis occurs the more active the tenderisation enzymes in the first few hours after slaughter and the more tender the meat will be by retail ready time.

Chilling and conditioning/ageing
Once the meat is in rigor mortis, tenderising (also known as conditioning or ageing) begins. This is the period during which the meat tenderizes through a gradual weakening of the muscle fibres. The rate at which this occurs depends upon the chilling and ageing temperature: the warmer the carcass or meat, the faster the rate of tenderisation. For all carcasses and/or primals, a period of ageing needs to be incorporated into a processing specification to ensure satisfactory tenderness levels are achieved. The aim of the ageing specification is to ensure that the product reaches the desired tenderness level before it is either offered for retail sale or frozen.

In practice, defining the appropriate electrical stimulation and chilling specification involves a number of considerations: First, the specific product type needs to be defined; for example, the optimum processing specification for a frozen product is very different from the requirements of a chilled product. Second, the specification needs to accommodate the particular operational requirements for any particular plant, such as chiller storage space or throughput rates. Third, the implementation of the specification needs to be consistent and reliable to ensure some consistency in the quality of the end product.

New Developments - Smart Stimulation (SmartStim)
SmartStim is the latest development in carcase stimulation. It determines the optimal stimulation to be applied to a given carcase by interpreting the response of the carcase to a "test probe". Initial validation trials have shown the variability between carcases to be reduced by 4-5 fold. The technology also controls some key attributes of the meat (pH and possibly ultimate pH and potentially objective tenderness, etc). Each carcase gets the exact dose it needs and the variability between carcasses is proven.

Smart Stimulation has been proven in prototype installations in beef and sheepmeat processing in one Australian and multiple New Zealand plant respectively to provide precise dose-controlled stimulation to individual carcases by first measuring carcase movement on a load cell in response to electrical inputs.

Processing to produce a high quality product, and identifying opportunities to create quality advantages and marketing opportunities, means finding the optimum balance between a number of sometimes conflicting requirements. These include identifying product quality requirements in specific markets, optimizing cost and benefits during processing and understanding the impact of processing events on meat quality attributes.

1.1 Key Components of SmartStim

Key commercial requirements:

- More sophisticated markets require consistent high quality products
- To attain this objective, processing conditions need to be consistent
- pH/temperature history is a critical component to effective processing
- Critical to this is the correct level of electrical stimulation (Refer to Figure 1)

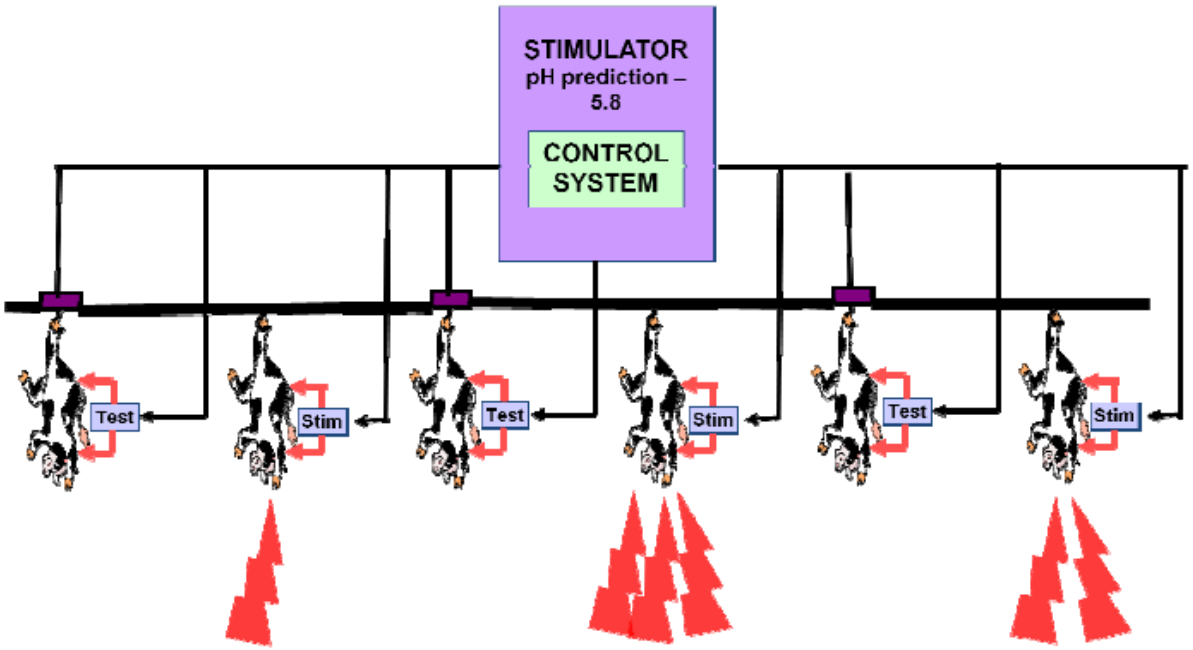


Figure 1: Overview of the key components of SmartStim System

The system

The variable responses to electrical stimulation (ES) have a number of sources but relate primarily to the rate at which the pH declines during ES and different thresholds to responsiveness at intermediate voltages. Clear differences in the contractile responses to otherwise identical stimulation conditions have been measured in both lamb and beef carcasses. To overcome this, SmartStim is based on measuring the responses of the carcass during stimulation and, from the nature of the responses, derive information about the pH of key muscles, and in particular the loin.

The procedure

To measure the response of the carcass, a load cell is mounted in the rail at the point where the stimulation takes place. In high throughput sheep lines, a number of load cells have been used. The load cells measure the rate of relaxation of the carcass to specific test pulses. Therefore, at intervals (typically 10-15 sec), and while the carcass is hanging from a load cell, a defined set of test pulses are introduced into the stimulation waveform, and it is the individual carcass response to these test pulses that are analysed to derive the pH information.

pH calculation

At this stage, the response characteristics are treated as a waveform whose frequency components are related to the pH. Consequently, the response waveforms are calibrated to the pre-rigor pH values as derived by direct probe measurement.

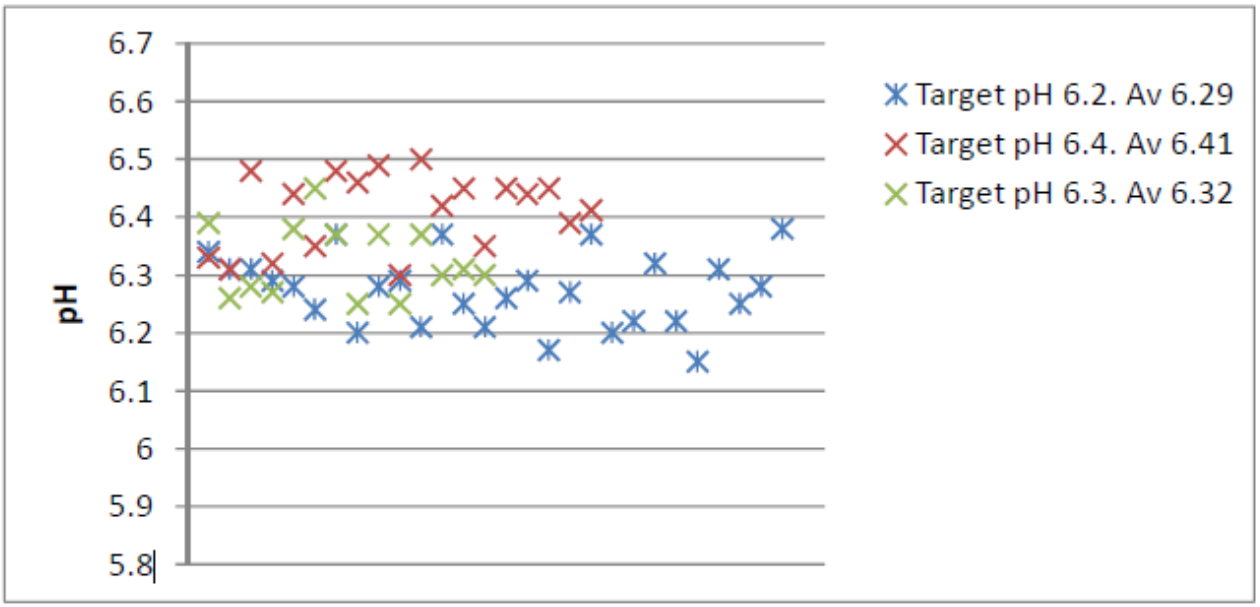


Figure 2: pH Calibration (February 2011)

Components of the SmartStim system

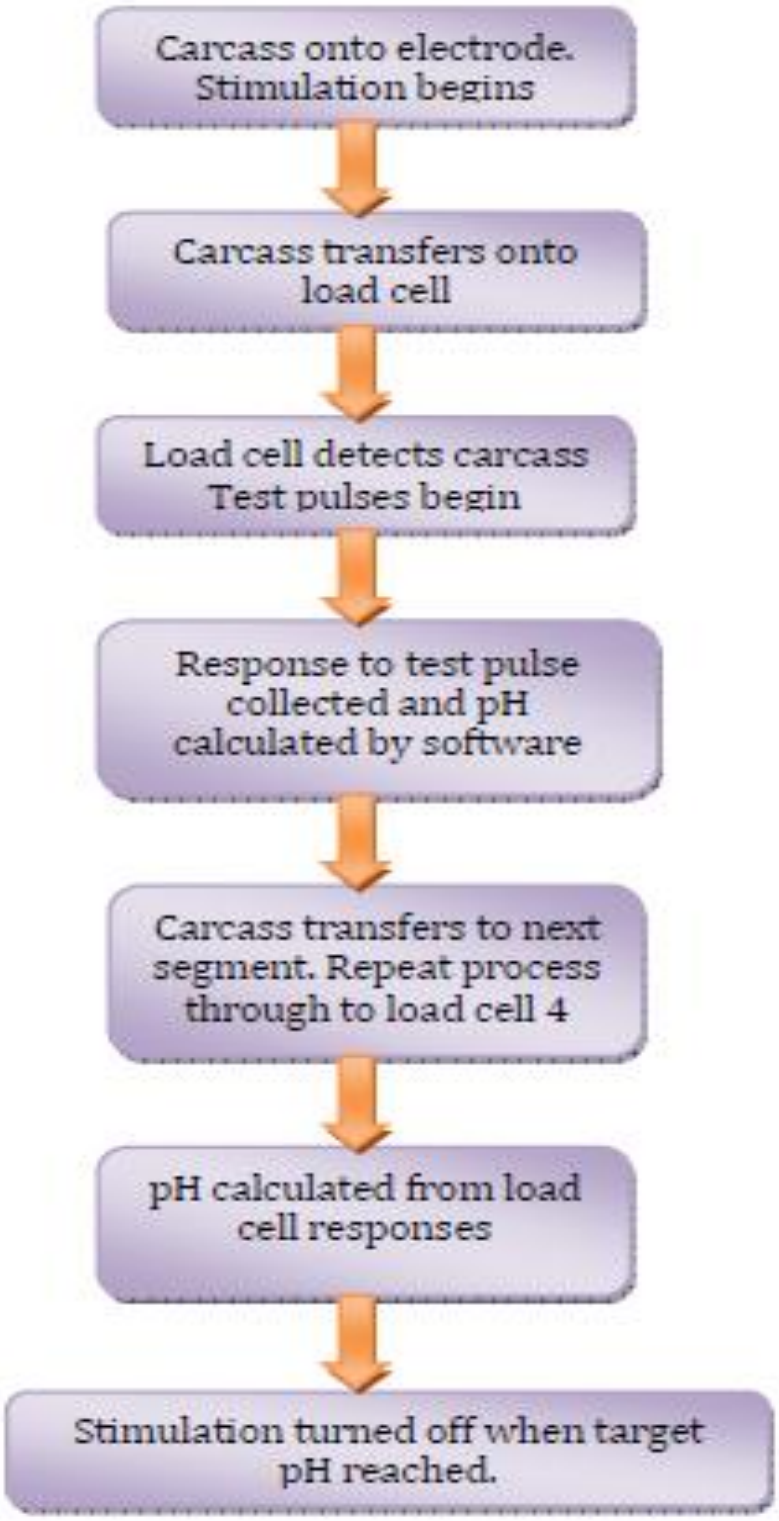
• Stimulation unit
• Load cells to measure the responses of individual carcasses to electrical stimuli
• A specified waveform to 'interrogate' the carcass, in order to effectively identify the required carcass attributes
• A software system that can provide: 1. the required processing specification (target pH) to be input; 2. the response characteristics to be acquired and analysed and the final pH calculated.

Control system – technical details

The control system is a PC-based LabView programme which interfaces through a National Instruments PCI6220 M series A/D card. The system accepts inputs from up to 8 load cells and can provide control lines for up to 25 segments. The load cell conditioners are positioned near the load cells and the amplified signal transmitted to the PC. The computer is located in the stimulation cabinet. The microprocessor also has an Ethernet hook up to allow remote access by Carne Technologies for system monitoring, support and upgrades.

Smartstim – Flow diagram

A simple flow diagram of the control system for the SmartStim system is shown below (See process Flowchart 1):



Flow Chart 1: Process flow chart of SmartStim System

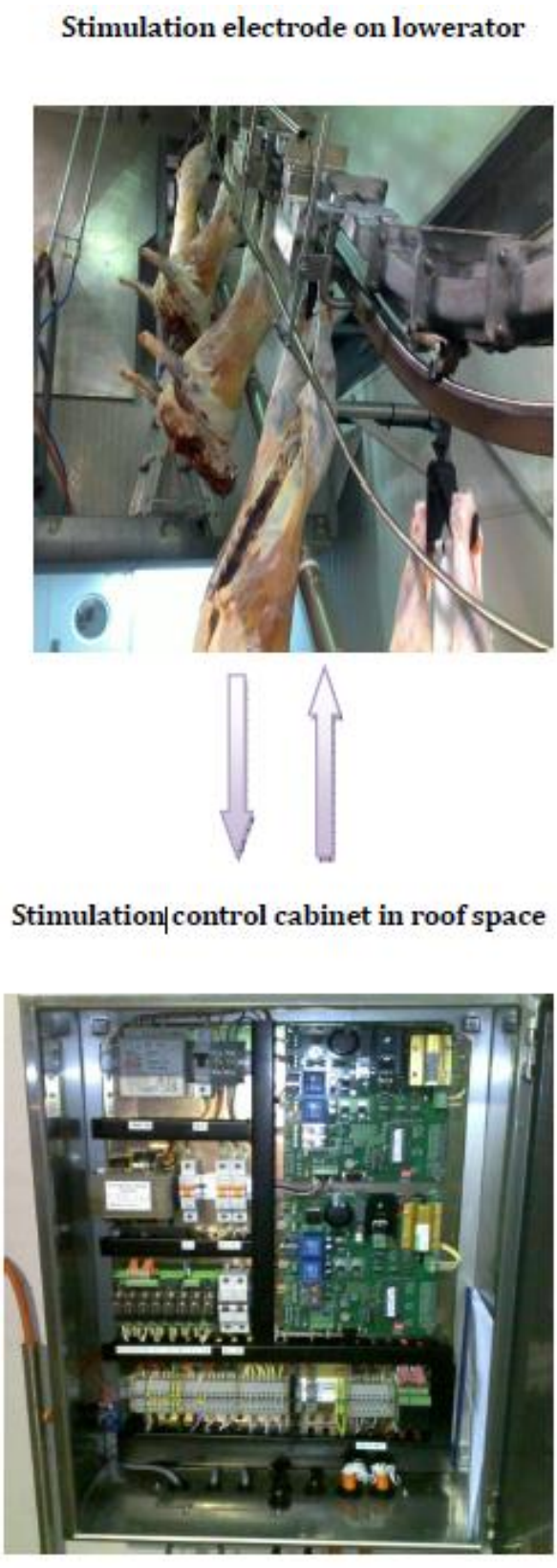


Figure 3: Critical components of SmartStim System

1.2 Commercial Proving

These pre-production commercial trials have demonstrated initially on beef in Australia that Smart Stimulation provides the optimum stimulation dose for each carcase, thereby reducing eating quality variations across entire production batches.

1. Meat electronics track record: Gen 1: Generation One electrical stimulation has delivered a large improvement in eating quality benefits when applied to all carcases. This has enabled a relatively unsophisticated commercialiser (Argus) to commission standardised hardware components. The level of meat science support needed for this level of sophistication has been met largely by MSA and limited testing capability by the commercialiser.

2. Learnings from the first prototype installation: A prototype SmartStim unit was installed at ACC in 2007 but did not function optimally. The installation identified improvements which have been incorporated into the current proposal. MLA & MWNZ assigned Carne Technologies as the sole contractor for installation and validation, providing scope for the contractor to choose sub-contractors as required

The key learnings are expected to be :

- assess and agree on the viability of the plant configuration before commissioning the project;
- ensure designs are acceptable by all parties (including sub-contractors) commissioning the project;
- allow scope for primary contractor to choose sub-contractors;
- gain upfront agreement from the processor on the targets & goals of the project and apply penalties if the processor intervenes or changes scope during the course of the project; and
- single point of contact should be with primary contractor (not via sub-contractor)

Also during the course of the project, an independent contractor, CSIRO's Neil McPhail would be contacting other potential SmartStim operatives & other related staff to investigate aspects of how well the technology had been serviced and maintained. Detailed reports both from the value proposition work and general serviceability of the project will be available to MLA & other interested companies in the technology.

1 Project objectives

This project will also evaluate the performance and reliability of the hardware and software components over a large number of carcases under typical commercial processing conditions. SmartStim will be used to measure carcases that tend to be more prone to heat toughening, where the system requirement is measurement and prediction, with less emphasis on stimulation. Where stimulation of lamb carcases is required, stimulation provided via up to 6 test cycles will reduce variability in quality and potentially improve eating quality attributes.

2.1 Research & Development

- Degree of variability (responses of lamb carcases) to stimulation delivered via SmartStim;
- The impact of SmartStim on the typical ranges of Australian cattle carcases
- Applications (in addition to proven pH measurement ability) of the technology and associated level of benefits;
- Relevance of the technology for beef with high natural incidences of heat toughening;

- Precision of improved quality of beef (ie reduced variability, enhanced quality and/or objective tenderness) when SmartStim is applied;
- Applications of SmartStim for specified targeted markets based on specific quality or eating quality attributes enhanced by the technology (eg enhanced meat colours without compromising eating quality); and
- Will the new benefits exceed Gen 1 meat electronics for safety and consistency

2.2 Adoption

- Meat electronics support requirements
- Benefits to sheep (& beef) installations
- How other small stock plant installations may differ and their adoption requirements
- At what level MSA should be engaged
- What the commercialisation business model should be

2 Methodology

The following milestones were used:

1. Initial consultation to establish the plants requirements of smartstim, assess and develop hardware requirements & installation
2. Conduct process audit and benchmark current meat quality outcomes Install hardware for smartstim system - stimulation electrodes, load cells and stimulation unit; operate the basic stimulation system (minus the feedback); audit process and meat quality outcomes
3. Set up control system (computer and software) Calibrate system and run initial validations Installation of remote access system Report on system performance
4. Technical support - 6 months of routine monitoring and optimisation of system using remote access One on-site audit to confirm meat quality outcomes Report
5. Upgrade PLC (M.O.M) & validation with new prototype wireless PUC system including hardware & software validation
6. System maintenance and validation of process outputs Modification to system as required 1 Year
7. Costs benefit analysis Report on the associated benefits of the technology to the industry
8. External expert technical advisor and follow-up with 2 companies on installation, support and service contract services during the project Assimilate a commercial business plan and adoption strategy based on the findings of the 2 projects

3.1 Basic stimulation set up and meat quality benchmarking

The stimulation hardware was installed and the stimulation parameters were set up and optimised. Once the electrical parameters of the system were optimised, the benchmarking trial was conducted:

- The pH fall was monitored in 50 lamb carcasses that had been stimulated and 50 non-stimulated carcasses. The first pH measurement was taken approximately 40 minutes after slaughter and then at regular intervals until the pH reached 5.8.

- The chilling of the carcasses were measured using temperature loggers that were inserted into the mid-loin position of three carcasses placed in different locations of the chiller. The air flow over these three carcasses was also recorded.

- At boning, 30 carcasses from each of the two treatment groups were selected (stimulated and non-stimulated) and both bone-out shortloins were removed from each of these carcasses. The shortloin samples were vacuum packed placed in a chilly bin with pre-frozen ice pads and temperature loggers. The samples were then transported back to NZ for evaluation. One shortloin from each carcass was analysed at 3 days post slaughter while the other shortloin from each sample was held at -1°C at Carne Technologies for 40 days and then analysed.

- After each of the two ageing periods, the purge loss during ageing was calculated from weight loss in the vacuum pack during storage. One shortloin from each carcase was then cut into two pieces; one was used for measuring cook loss and shear force (tenderness), and the other for colour stability and drip losses during retail display.

- Meat quality evaluations consisted of:
  - pH
  - Shear force
  - Purge loss during vacuum packed storage
  - Cook loss
  - Drip loss during overwrapped retail display
  - Colour stability during overwrapped retail display

- Meat quality evaluation procedures

Fluid Losses

Fluid losses reflect the water binding capacity of meat and can take the form of drip during vacuum packed ageing, drip in retail packs and fluid loss during cooking. Processing conditions that maximise water binding capacity of meat reduces weight loss as purge, improves retail appearance and benefits eating quality by contributing to juiciness and succulence.

Drip loss during vacuum packed chilled storage

Each sample was weighed in the vacuum pack and the packaging was then removed. The packaging and the cut was dabbed dry using paper towels and the cuts and packaging were re-weighed independently to enable calculation of purge loss. The results are presented as percentage of drip.

Drip loss during overwrapped retail display

Sample weight was recorded before and at the end of the retail display period to calculate purge (drip) loss.

Colour stability during overwrapped retail display

Colour readings were taken daily from samples that had been overwrapped and displayed at 4°C. The colour was expressed as a* values, a measure of the redness of the meat. Colour meter values of less than a* 12 are unacceptable, as defined by consumer tests, which represents a loss of redness and a predominance of brown.

Cook loss
Samples were cooked prior to shear force assessment. The weights of the loin samples before and after cooking were used to evaluate cook loss.

Ultimate pH
The ultimate pH of each sample was measured using an Orion pH meter and Anode spear-tip probe. The probe was inserted into the meat and the pH recorded from two different locations within the sample. The average for the two readings was calculated.

Tenderness
Loin samples were cooked in a 100°C water bath until the internal temperature of the meat reached 75°C, the samples were then removed from the waterbath and immediately cooked on ice. Once the samples had cooled to 4°C each sample was cut into ten rectangular samples or 'bites'. These samples were cut precisely to a specification of 1cm x 1cm cross section. The samples were then sheared at right angles to the meat fibres using a pneumatic Tenderometer which is effectively a mechanical tooth. The amount of pressure required to cut through the sample with the tooth was measured and expressed as kilograms force (kgF). The commercial specification that is typically used for both beef and lamb is:

• Mean shear force reading to be 8 kgF or less
• 95% of the 'bites' to have a tenderness reading less than 11 kgF

The relationship between the shear force as measured by a Tenderometer, and NZ and UK consumers is shown below:

Table 1. Relationship of shear force to consumer acceptability Shear force values (kgF) Consumer response

Shear force values (kgF)	Consumer response
Less than 5.0	Very Tender
5.0 to 7.9	Tender
8.0 to 10.9	Acceptable
11.0 and above	Unacceptably tough

Taken from Bickerstaffe *et al*, 2001

4 Results and Discussion

4.1 Basic stimulation set up and meat quality benchmarking

The stimulation system was installed and commissioned. The electrical parameters of the system were set up to provide an appropriate pH drop from the stimulation that is optimal for chilled export lamb – the predominant product being produced by this plant.

The meat quality of shortloin samples from both stimulated and unstimulated carcasses was assessed after both 3 and 40 days of ageing.

The new stimulation system generated an improvement in overall meat quality:

- The tenderness was significantly better after both 3 and 40 days of ageing in the stimulated samples: the unstimulated samples were of acceptable tenderness at 3 days but improved to very tender following stimulation whereas all product was in the very tender category by 40 days.
- The weight losses during vacuum packed chilled storage, chilled retail display and cooking were all reduced in the shortloin samples from electrically stimulated carcasses.
- The colour stability of the shortloin samples during retail display was not affected by the stimulation.

pH fall

The pH fall was measured from both non-stimulated and stimulated carcasses. On average, the stimulation dropped the pH by 0.5 of a pH unit and, during chilling, the pH continued to fall at a faster rate in the stimulated carcasses. The time to rigor mortis was in excess of 16 hours in the unstimulated carcasses and this was reduced to 5 hours with the stimulation system.

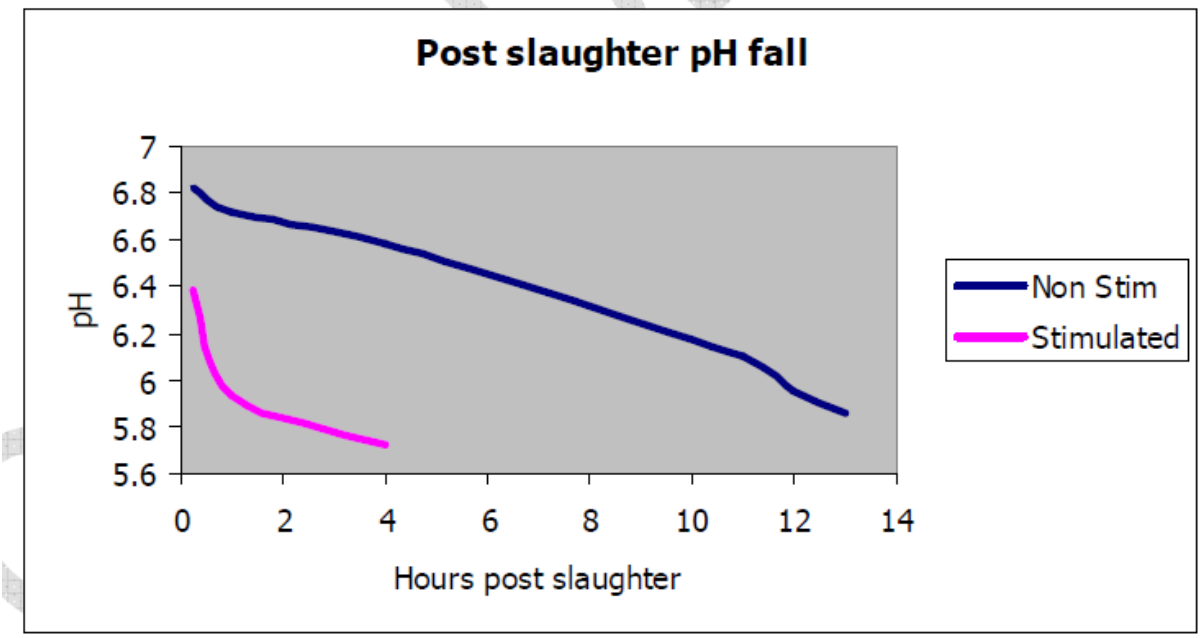


Figure 4: pH fall

Carcass chilling

The carcass chilling was relatively slow: the temperature in the mid loin reached 5'C in approximately 10-12 hours after slaughter, and this temperature was maintained until boning the following day.

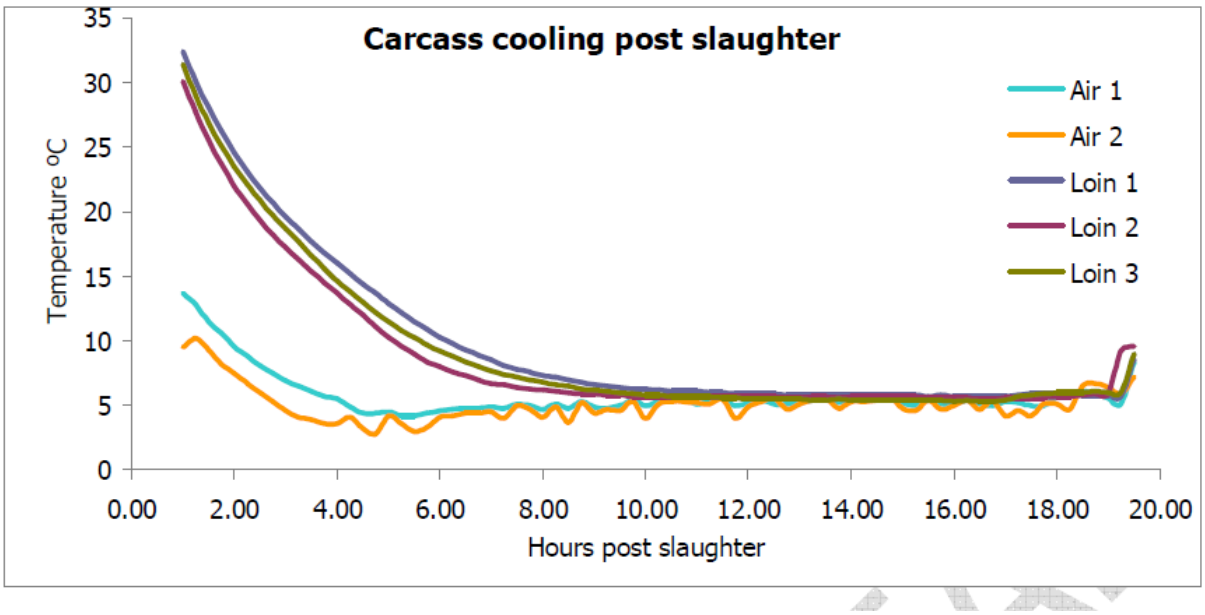


Figure 5: Carcase cooling temperatures

Temperature of samples during transit

The temperatures of the shortloins were between 5 and 6'C at the time of packing into a cool bin for transfer to NZ. However, despite the inclusion of ice blocks in the bin the sample temperatures increased by, on average, 2-3 degrees during transport. However, once they reached the Carne Technologies chiller, the samples were chilled quickly to -0.5'C. All samples were maintained at this temperature during the storage period prior to evaluation at 3 and 40 days post slaughter.

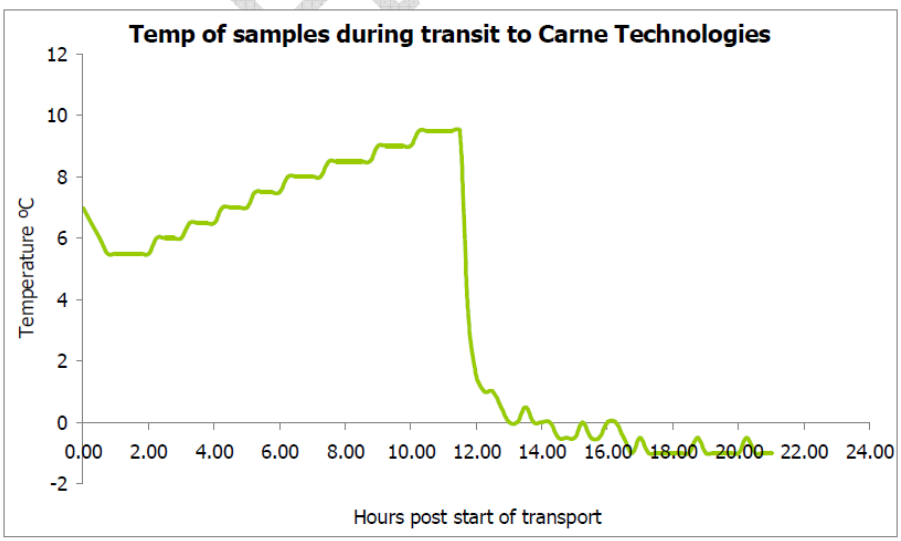


Figure 6: Temperature of samples during transit

Ultimate pH

The ultimate pH's of all samples were in the acceptable range of 5.4 to 5.6. As would be expected, there was no significant effect of stimulation on the final pH although the trend was for

the stimulated samples to have a slightly lower pH after both 3 days and 40 days of storage; these differences do not have any commercial relevance.

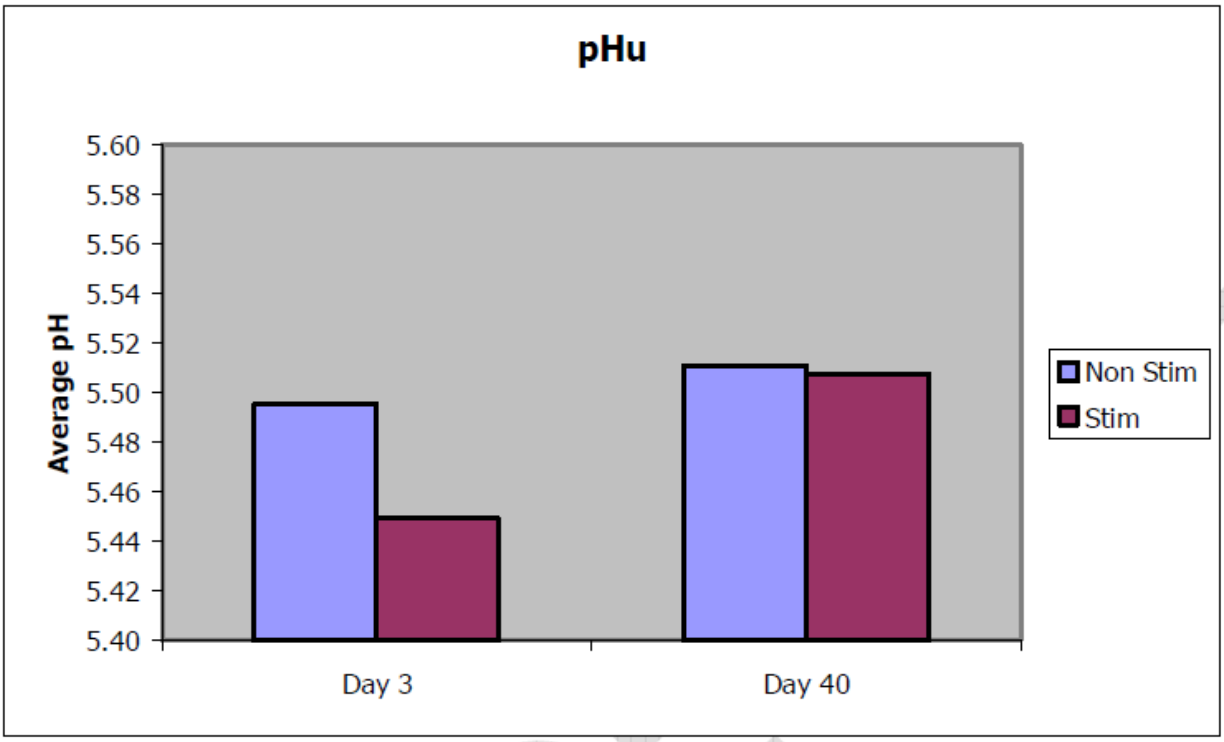


Figure 7. Ultimate pH after 3 and 40 days of storage

Purge/drip loss during vacuum packed storage

At 3 days post slaughter the average drip loss was 1.02% for stimulated samples and 1.45% for non-stimulated sample. The drip losses at day 3 were generally higher than industry averages but this was almost certainly due to the temperature increase during transit to NZ and, to a lesser extent, the relatively slow carcass chill at the plant. At day 40 the drip losses were in keeping with industry figures and there was significantly less drip loss from the shortloins that had been taken from the electrically stimulated carcasses (2.64 vs 2.08%).

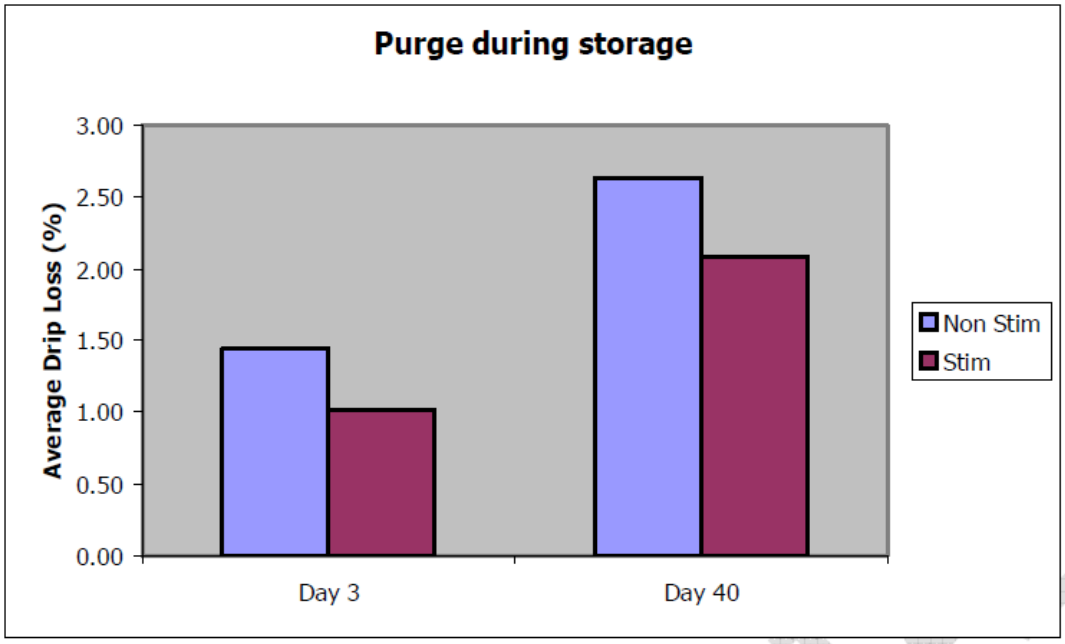


Figure 8. Purge or drip loss after 3 and 40 days of storage

Purge loss during overwrapped retail display

The weight lost as drip during overwrapped retail display was also less in the stimulated samples. While the difference in drip loss tended to be most marked in the 3-day samples these differences were still evident in the 40 days samples.

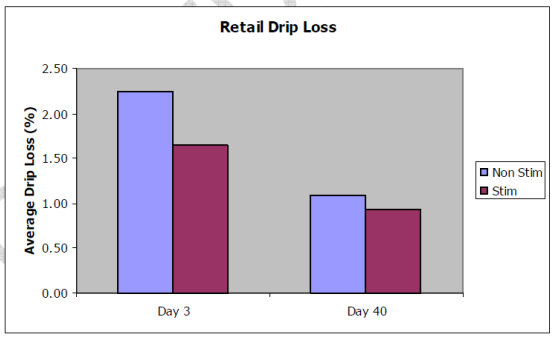


Figure 9. Purge losses from boneless lamb chops during a simulated retail display period and following either 3 or 40 days of storage

Cook loss

The samples from the stimulated carcasses lost 30% of their weight in fluid while the non-stimulated samples lost 32%, after 3 days post slaughter. Overall the cook losses tended to be higher in the samples that had been held for 40 days, but as before, the losses tended to be less from the stimulated samples. Typically loin samples lose between 25-35% of their weight during cooking and so these losses are consistent with typical commercial figures, irrespective of ageing period.

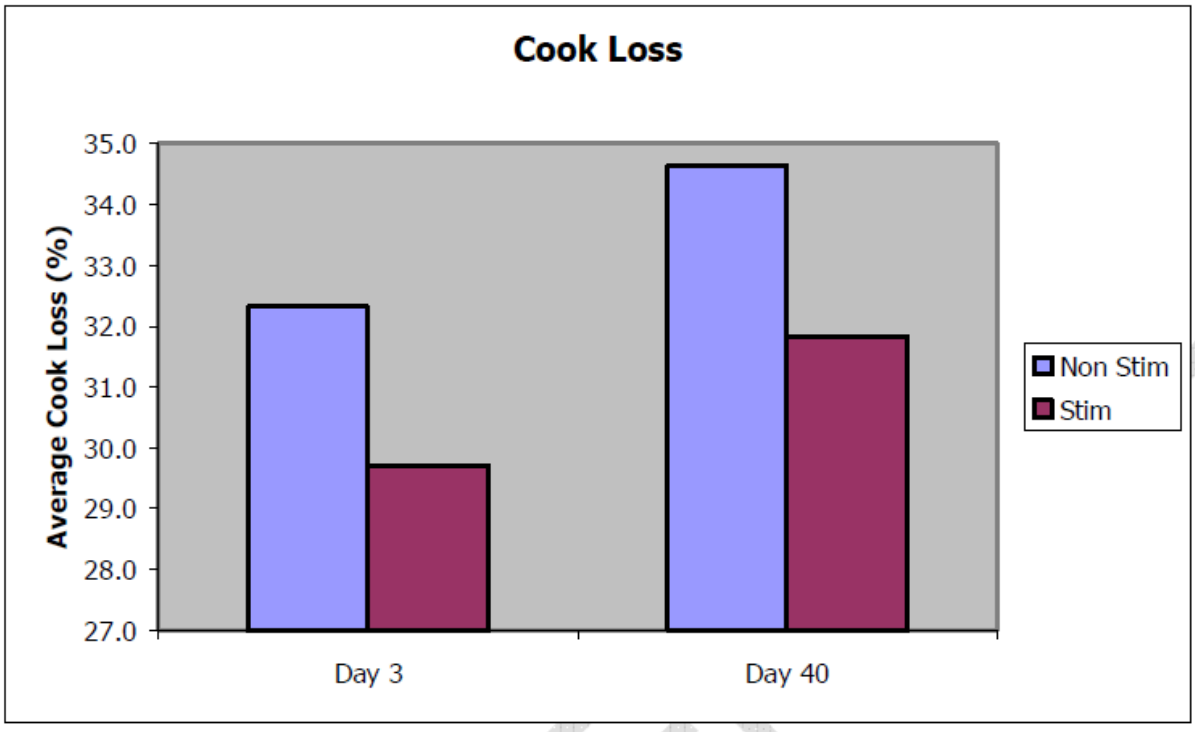


Figure 10. Cook loss after 3 and 40 days of storage

Tenderness

The samples from the stimulated carcasses had significantly lower shear forces and were therefore more tender at both 3 and 40 days post slaughter; while these differences were most marked after 3 days (8.3 vs 4.9 kgF) they were still evident after 40 days (4.4 vs 2.9 kgF). In addition the samples from the stimulated carcasses were more consistent after both ageing periods (Figure 11). This is evident in the tenderness histograms below (Figure 12).

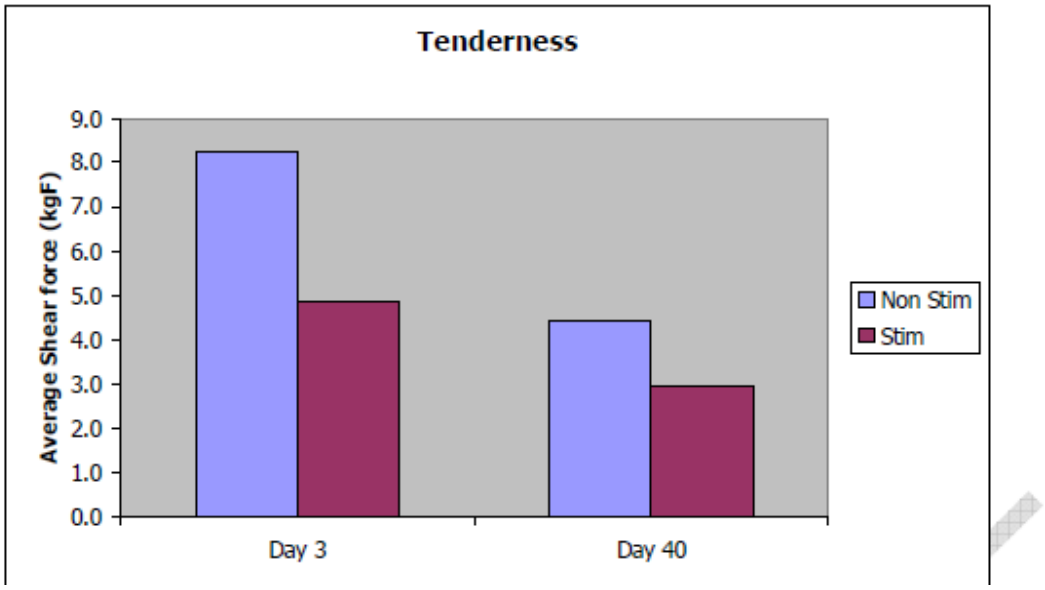


Figure 11. Cooked shear force after 3 and 40 days of storage

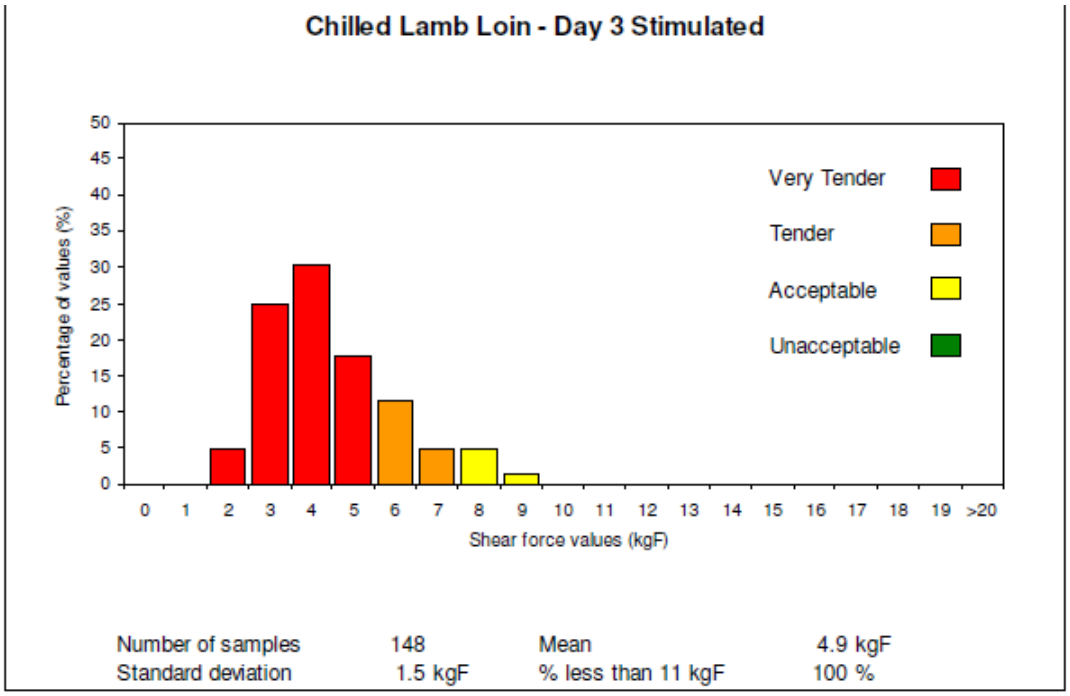
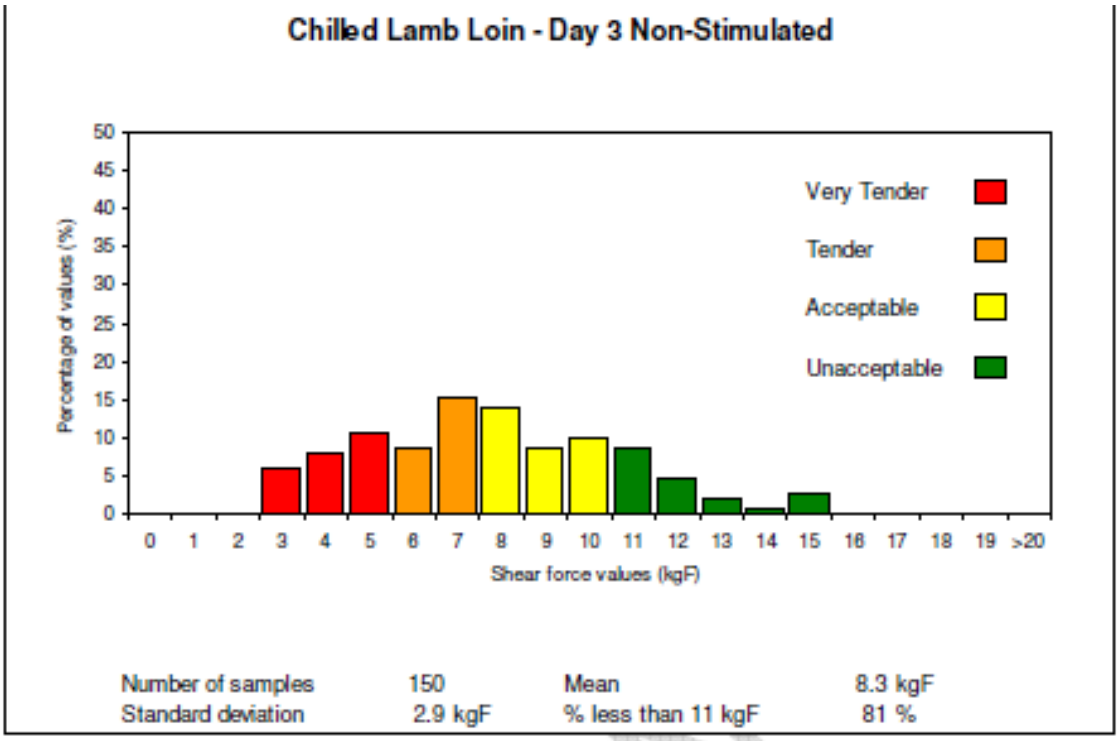
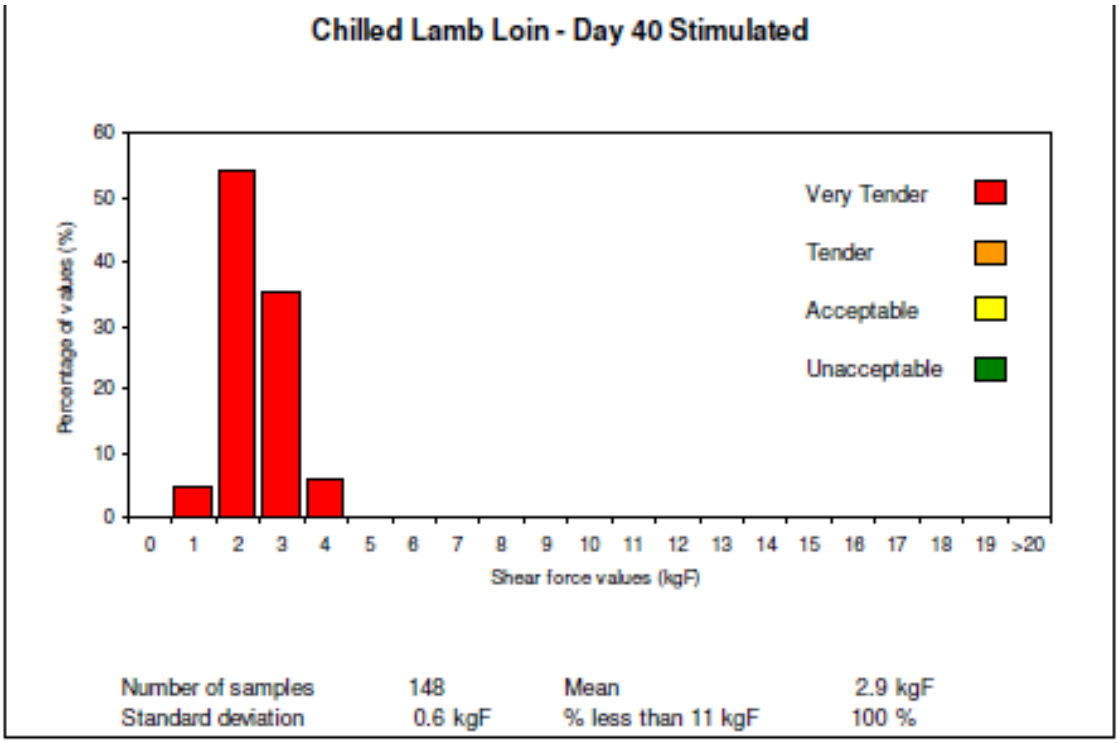


Figure 12. Cooked shear force after 3 and 40 days of storage


Chilled Lamb Loin - Day 3 Non-Stimulated
Percentage of values (%)
0
5
10
15
20
25
30
35
40
45
50
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 >20
Shear force values (kgF)
Very Tender
Tender
Acceptable
Unacceptable
Number of samples 150
Mean 8.3 kgF
Standard deviation 2.9 kgF
% less than 11 kgF 81 %


Chilled Lamb Loin - Day 40 Stimulated
Percentage of values (%)
0
10
20
30
40
50
60
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 >20
Shear force values (kgF)
Very Tender
Tender
Acceptable
Unacceptable
Number of samples 148
Mean 2.9 kgF
Standard deviation 0.6 kgF
% less than 11 kgF 100 %

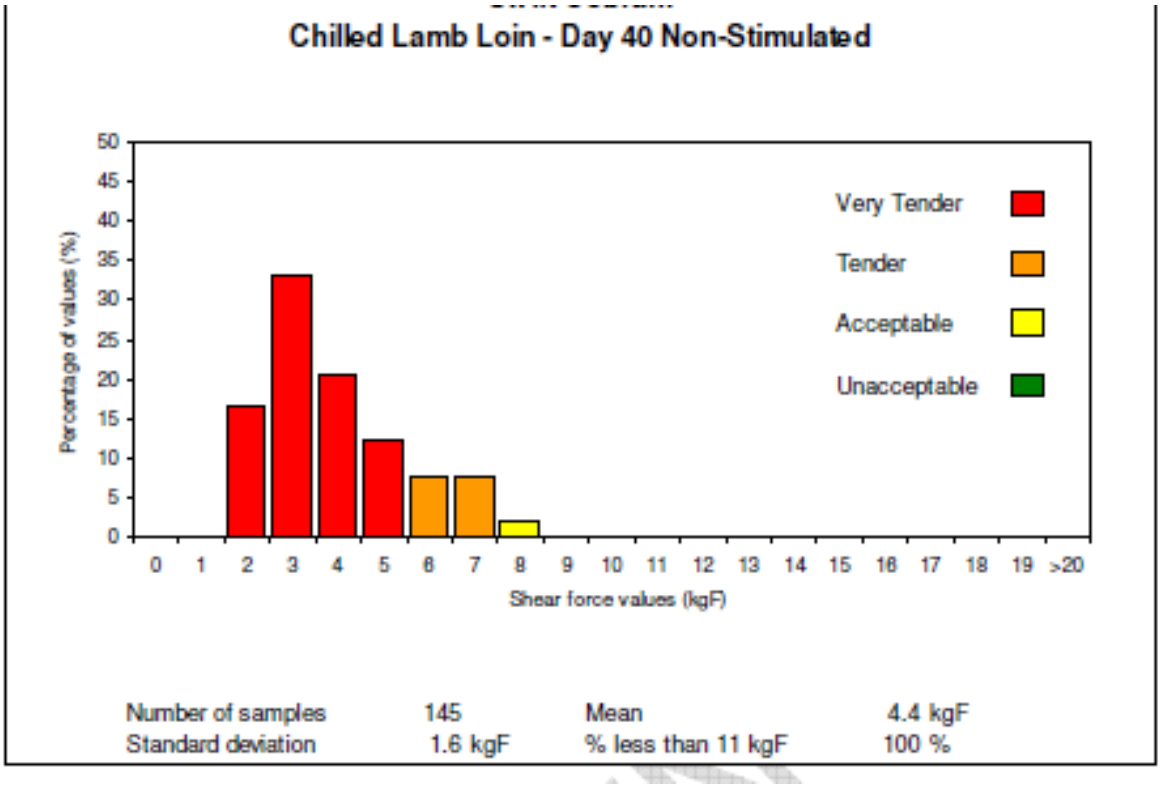


Figure 13. Shear force histograms

The histograms above show that the stimulation has improved the tenderness at both 3 and 40 days post slaughter. The average shear force was improved by 3.4 kgF units at day 3 and the percentage less than the 11 kgF cut-off was only 81% in the non stimulated samples while all stimulated samples were less than 11 kgF. After 40 days, the average shear force from the stimulated samples was 2.9 vs 4.4 kgF from the non-stimulated samples. While the average shear force of both sets of samples fall within the 'very tender' category after 40 days of ageing, the tenderness of the stimulated samples were far more consistent than the unstimulated samples, as can be seen from the histograms above.

Overall, compared to the Carne Technologies commercial database, the stimulated samples at 3 days post slaughter are better than the industry average while the non-stimulated samples are slightly worse than the industry average. However, while the stimulation has clearly produced a significant improvement in tenderness, the increase in temperature during transit will have produced in some additional ageing during this short period.

After 40 days the tenderness of both sets of data are comparable to the range of shear force values in the commercial database for chilled export lamb.

Colour stability

The colour stability of the shortloin samples was broadly equivalent for both stimulated and unstimulated samples; the average a* values remained above the cutoff point of 12 for 4d ays for samples that had been held for 3 days post slaughter and this increased by one day following the 40-day ageing period. Overall, these results are comparable to the NZ industry average for chilled lamb.

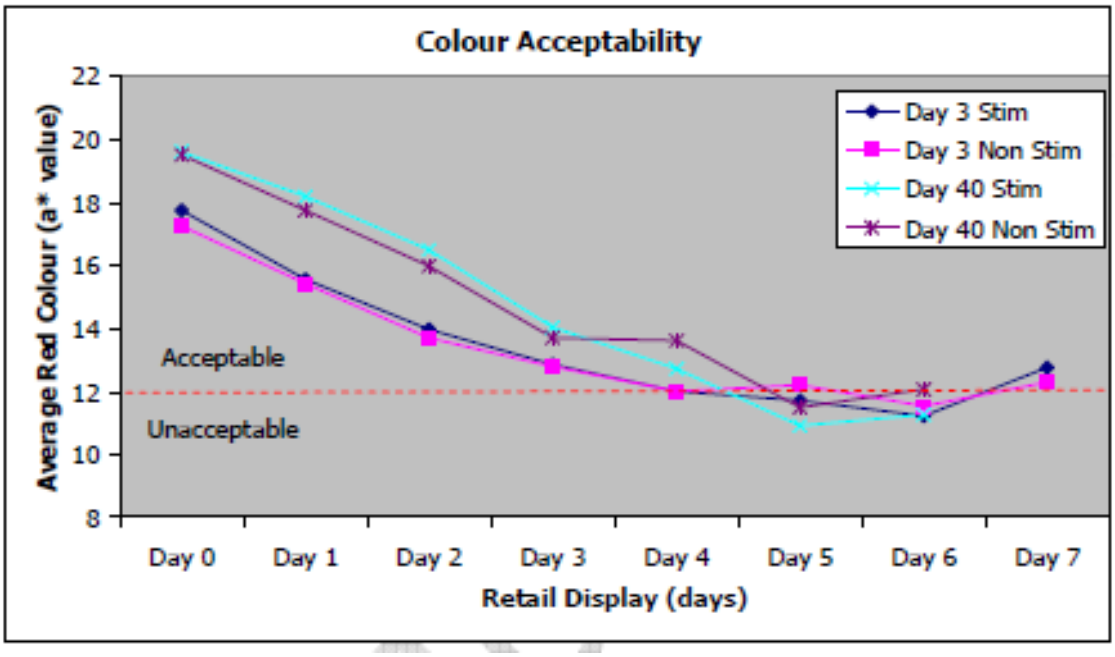


Figure 14. Colour stability of boneless lamb chops during a simulated retail display period and following either 3 or 40 days of storage

The stimulation system significantly improved the meat quality of the chilled lamb. In particular, the purge or drip losses during vacuum packed storage are significantly reduced while the tenderness after both short and long-term ageing is significantly increased, as measured by both the average shear force and its variability.

4.2 Setup and test parameters

1. pH decline:

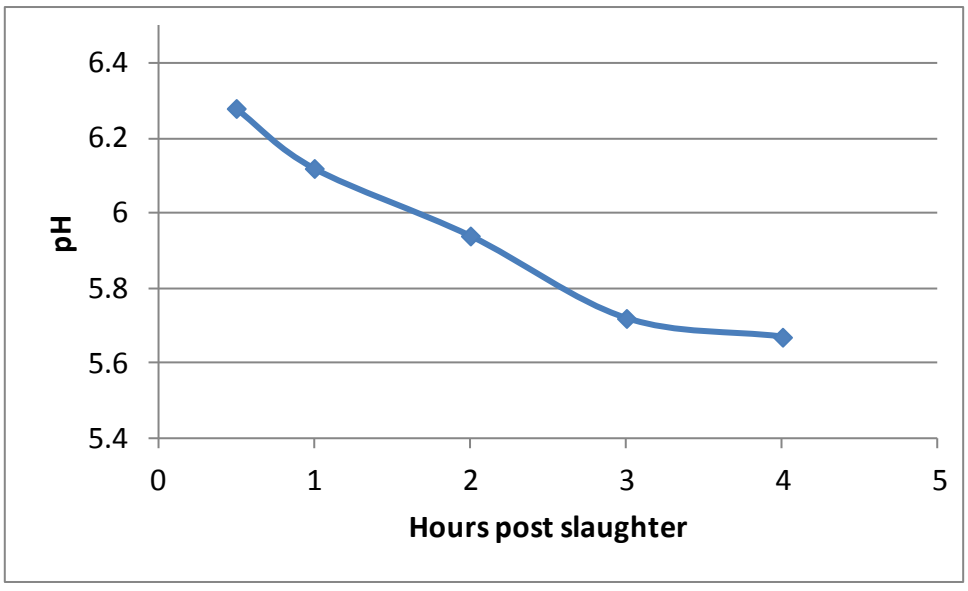


Figure 15: Average pH fall

The pH within a few minutes of stimulation averaged 6.28 and continued to fall during chilling to achieve rigor mortis between 4 to 5 hours after slaughter (Figure 16).

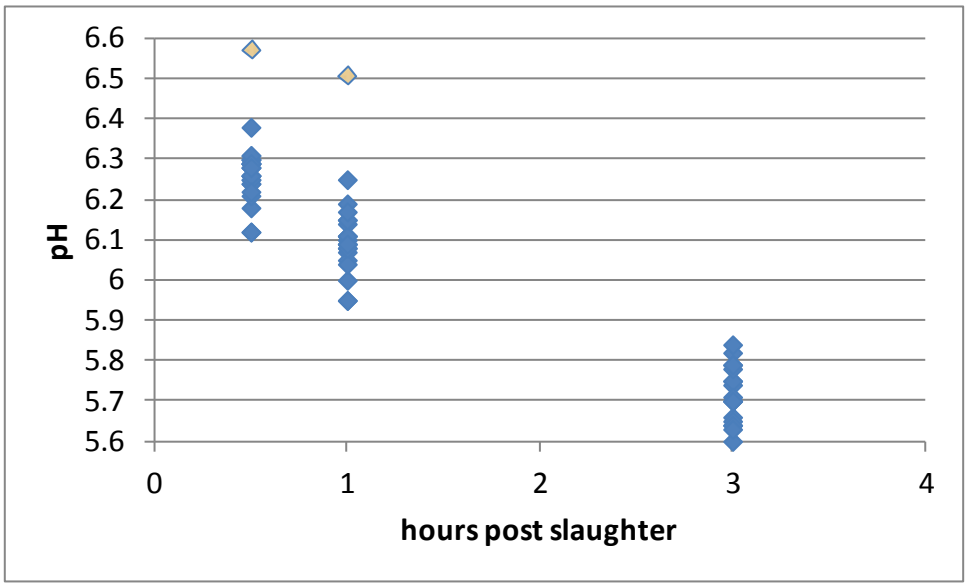


Figure 16: pH fall following stimulation in a range of carcasses

Most carcasses were within +/- 0.1 of the target pH of 6.25 which is appropriate for this system. Several carcasses were clearly high pH (dark cutters) and the high pH in the dataset above is given a light colour to distinguish it from the carcasses that were later measured as having a 'normal' ultimate pH (5.4 – 5.6).

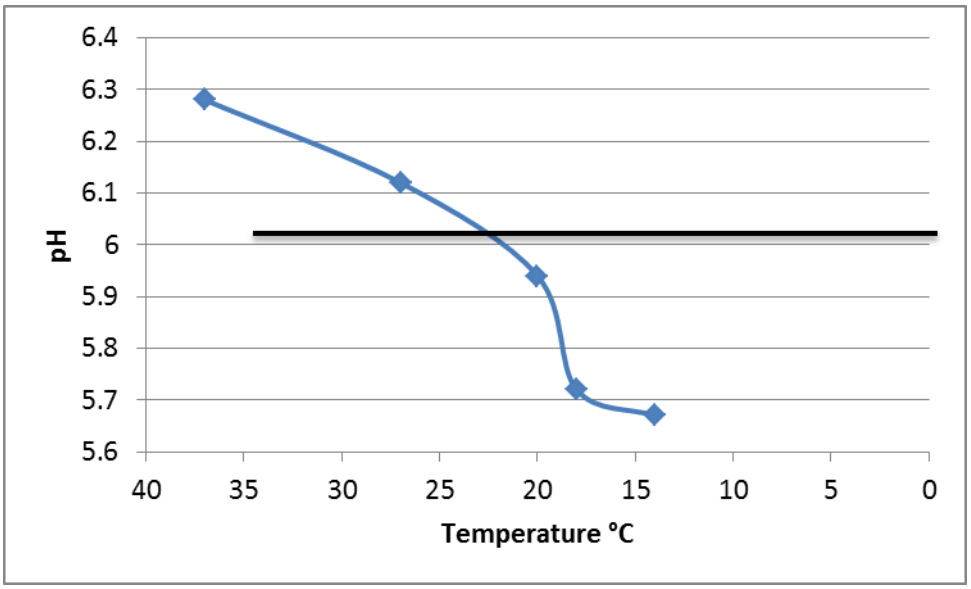


Figure 17: Average pH/temperature window

The graph above shows that the combination of SmartStim and the subsequent chilling caused the carcasses to pass through the 'window' at approximately 22°C. It should be noted however that the carcasses used for these validations were railed into a chiller that was only partially loaded and, therefore, the air flow around the carcasses was high and produced a faster 'pull-

down'. Carcasses in fully loaded chillers would be expected to chill slightly slower and the prediction is that these would pass through the window at approximately 25°C.

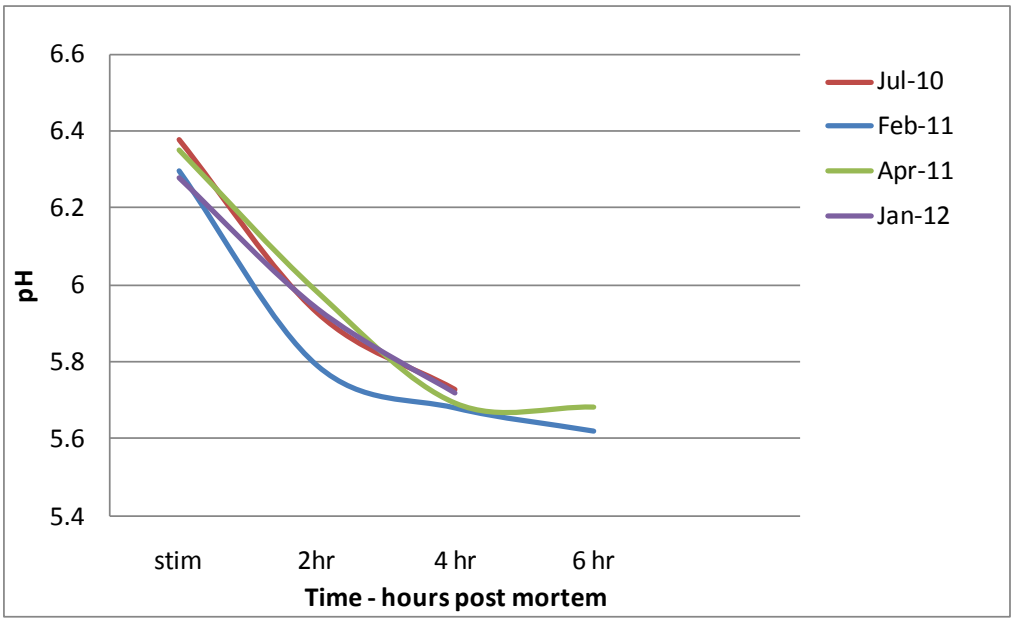


Figure 18: Average pH decline

The pH fall has been consistent over the 4 visits. In February 2011 the pH decline was slightly faster and this was due largely to the slightly slower chilling recorded during this visit (Figure 19). Since then the chilling, as measured by temperature logging devices in a selection of carcasses, has been consistent and the SmartStim has continued to control the pH in line with the target of between pH 6.2 to 6.3 post stimulation and a rigor time of between 4 to 5 hours from slaughter. In combination with the 2 chilling regimes (Tesco kill – chiller set points 1.5°C and local market kills – chiller set points of 3°C), this pH/temperature environment will provide good meat quality outcomes for both the chilled local and chilled export markets.

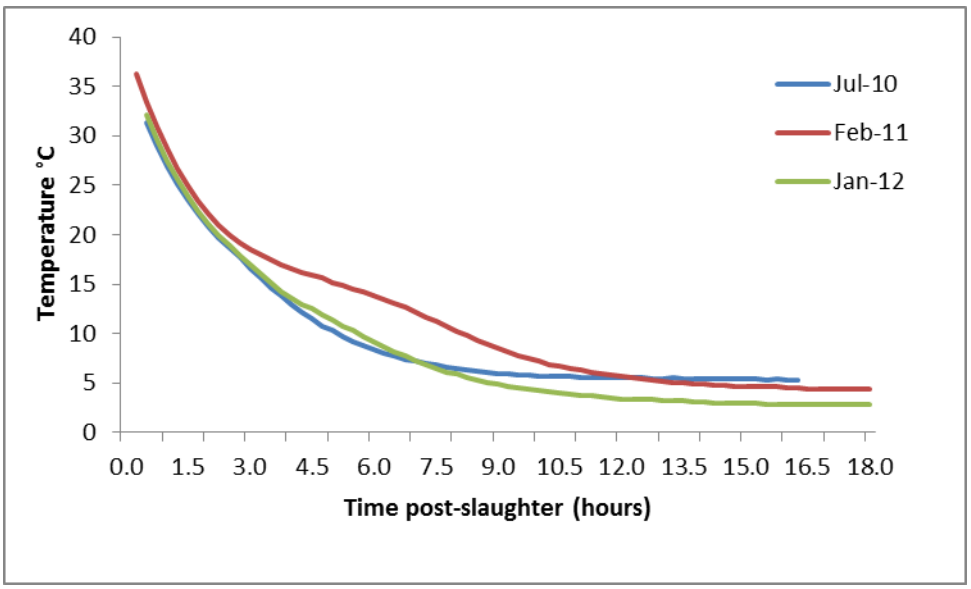


Figure 19: Average chilling curves as measured in the mid-loin position

2. Meat quality outcomes:

15 lamb carcasses were selected at random from the chiller

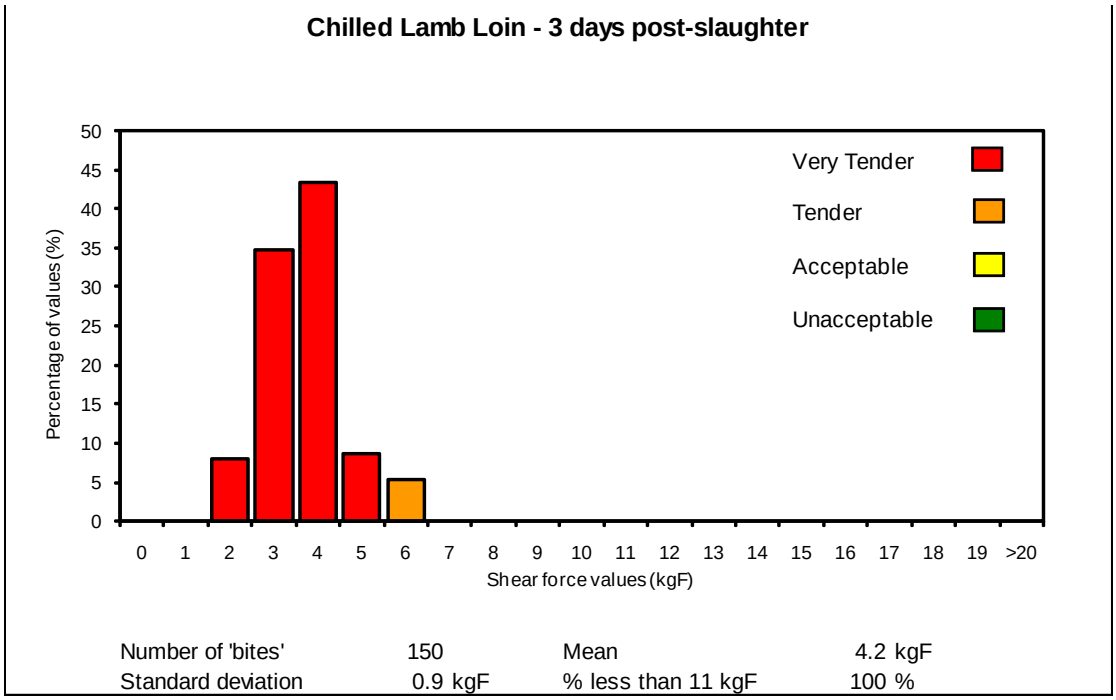
- The chilling of two of these carcasses were measured using temperature loggers that were inserted into the mid-loin position.
- At boning, one boned-out shortloin was removed from each of the 15 carcasses. The shortloin samples were vacuum packed and transported to the processor where Carne staff undertook the meat quality evaluations. The shortloins were analysed 3 days post slaughter.
- Meat quality evaluations consisted of:
    - Drip loss during vacuum packed storage
    - Ultimate pH
    - Shear force
    - Cook loss

The results are shown below along with the historical records of the 4 meat quality evaluations.

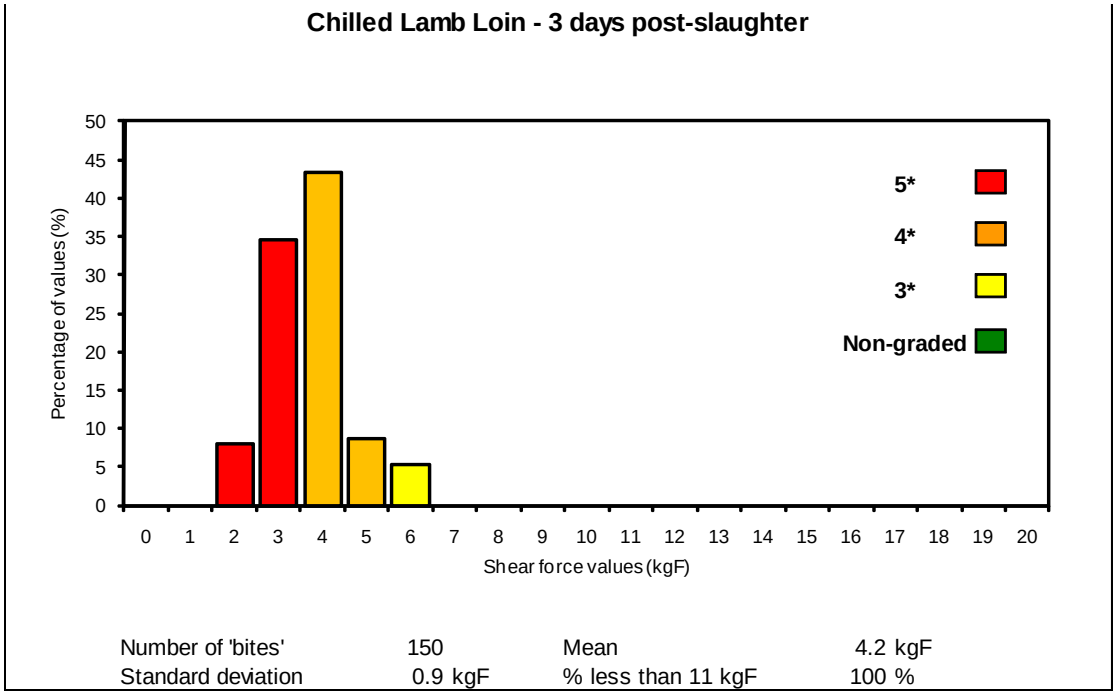
Tenderness: The tenderness was measured on the 3rd day after slaughter. The shear force values in the histograms below are presented as both consumer acceptability and MSA scales.

The shear force results show that the samples were highly acceptable and the majority of samples fell in the Very Tender category - equivalent to either a 4 or 5* MSA grade. The overall shear force average is slightly lower than for earlier evaluations and the variability between samples is low.

Drip loss: The drip loss from the samples during the 3-day period is consistent with the earlier evaluations and is in keeping with industry averages for chilled boneless shortloin stored for similar periods.



Number of 'bites'	150	Mean	4.2 kgF
Standard deviation	0.9 kgF	% less than 11 kgF	100 %



Number of 'bites'	150	Mean	4.2 kgF
Standard deviation	0.9 kgF	% less than 11 kgF	100 %

Table 2. Comparison of meat quality over the 4 evaluations				
	Non-stim	Stimulated		
	Jul-10	Jul-10*	Feb-11	Jan-12
Drip Loss %	1.44	1.02	2.0	1.2
Cook Loss %	32.3	29.7	30.3	31.9
Shear force (kgF) – 3 days	8.3	4.9	5.1	4.2

*basic stimulation prior to implementation of the feedback system

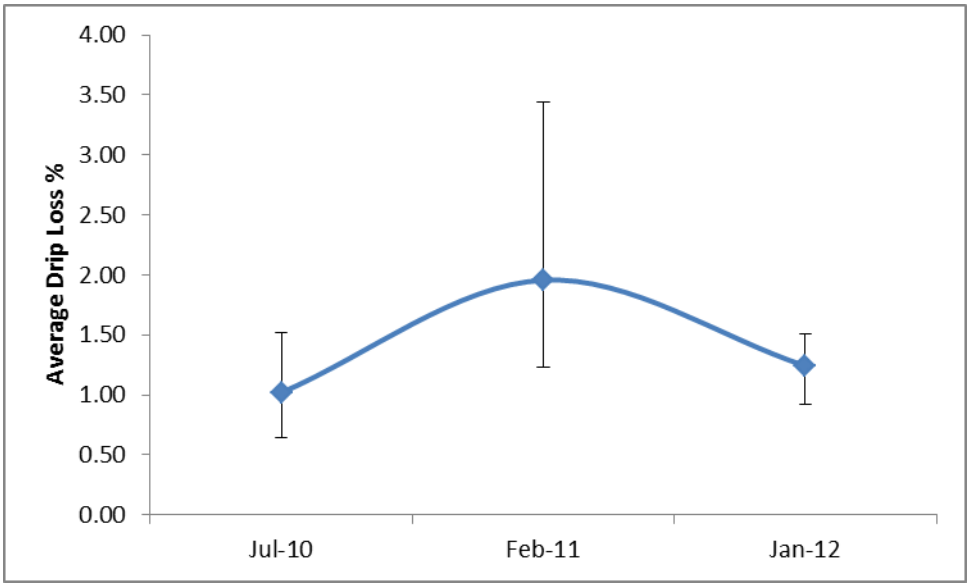


Figure 20: Drip loss fluctuation following installation of the stim system

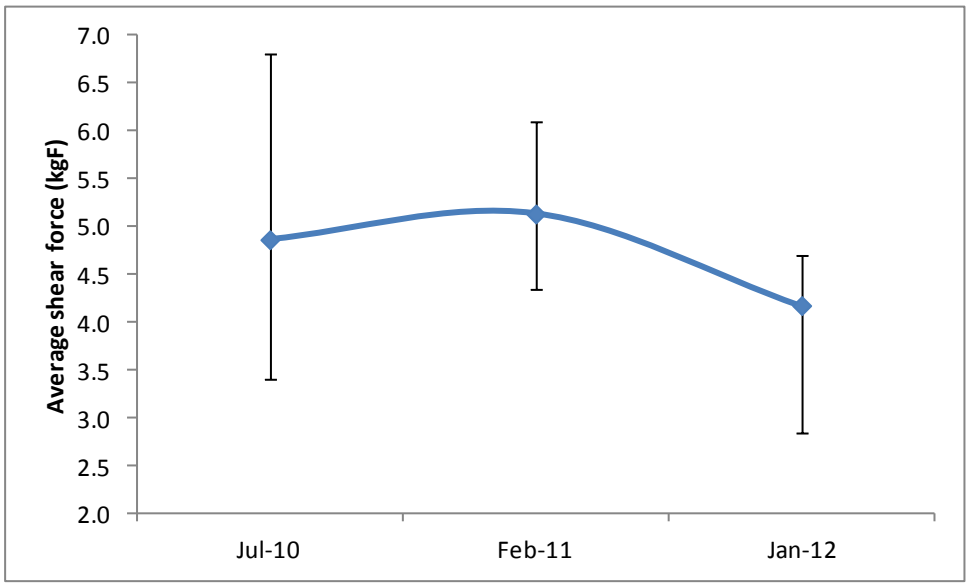


Figure 21: Shear force fluctuation following installation of the stim system

5 Commercial Outcomes

5.1 The following were the plant considerations:

- Ideally all carcasses should make contact with the stimulation rail on their backs rather than bellies. Previous visits had identified that this did not always occur, so during the April 2011 visit, the top guide rail was extended to the grading point. This was to allow the grader to correctly orientate the carcasses and the guiderail then maintains this orientation until the carcass is transferred to the stim rail. During this visit it was apparent that this is not happening consistently, so that a large number of carcasses were railing down the stim rail on their bellies.

- On occasion a very small carcass will swing out away from the rail just at the top of the lowerator and before the stimulation starts. This can result in the carcass sliding to the wrong side of the electrode and being dragged down over the horizontal supports. To avoid this, the recommendation is to install an additional rail above the first section of stimulation electrode.

- On occasions, the stimulator is not switched on, typically after a break. Carne generally pick this up when carrying out the daily log in and phone the plant to ask someone to turn it on. This needs to be addressed by ensuring that the system is checked at the start of every kill and after every break.

5.2 SmartStim System

i) Electrode system
   - rubbing rail electrode on lowerator. Post grade/pre chill
   - 4 loadcells

ii) Stimulator
   - Twin card system. Unit located in roof space above kill floor

iii) Computer & software
   - Microprocessor and hard drive in stimulation cabinet

5.3 Controlling pH decline

The SmartStim system has four load cells mounted to the carcass rail above each segment of the stimulation electrode. These loadcells are used to measure the response of the carcasses to specific electrical test pulses embedded within the electrical stimulation waveform. These test pulses trigger characteristic muscle contraction cycles in the carcasses that create the appearance of a weak ‘bouncing’ in the carcass. These cycles occur once on each segment.

The analysis of the loadcell responses for each carcass is carried out by the software. The analysis focuses on specific features of the responses and uses these to calculate the pH at that time. This calculated pH is then compared to the target pH; if the carcass has reached the target pH then it receives no further stimulation. If it has not yet reached the target pH then another segment of stimulation is given before the carcass is then tested again.

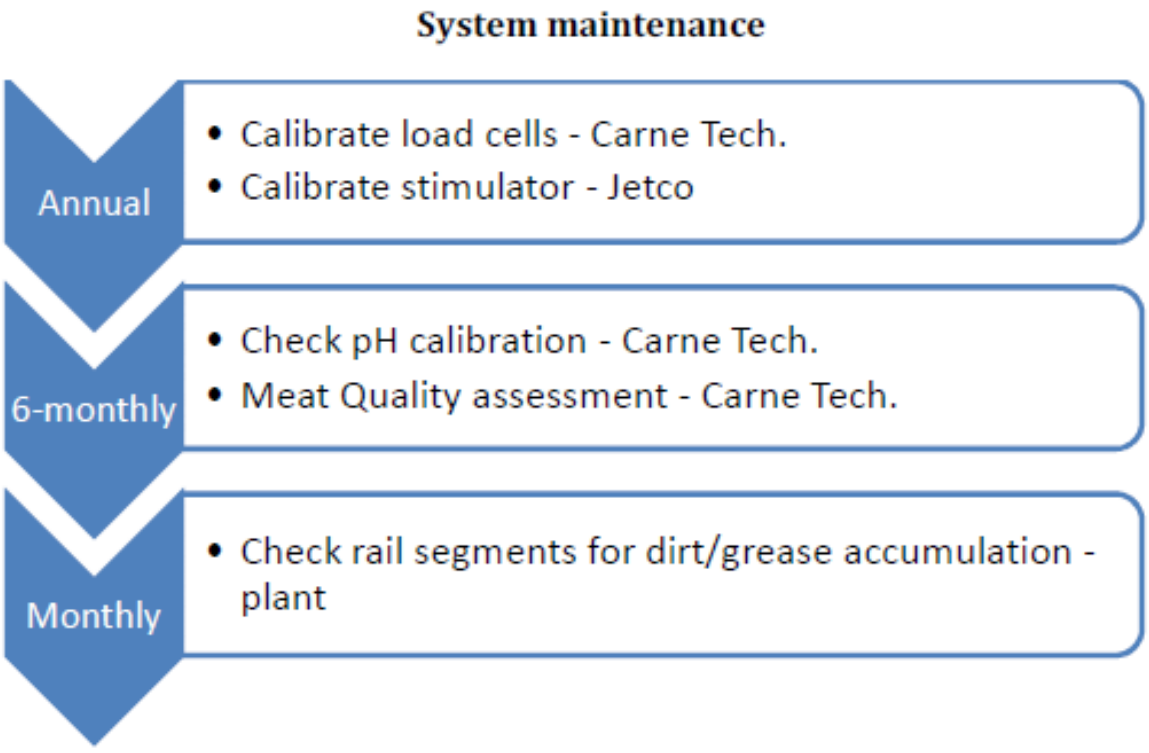
5.4 Critical operational requirements

i) **Ensure that the carcass orientation puts the back of the carcass ('loin side') in contact with the electrodes:**
Contact with the 'belly side of the carcass will cause the carcass to contract away from the electrodes, which can cause uncontrolled bouncing of the carcasses and will prevent accurate pH calculations.

ii) **Carcasses should never be manually pushed through the stimulation system:**
The software needs to maintain the synchronization of the carcasses to ensure that a calculated pH is allocated to the correct carcase.

iii) **Delays before the carcass reaches the SmartStim rail will lead to poor pH predictions and therefore control.**
The pH of the carcasses needs to be above 6.5 to ensure effective responses to the test pulses and accurate pH control. Carcasses that have been on the detain rail for prolonged periods may not respond adequately to the test pulses and therefore the accuracy of the pH prediction will be affected.

5.5 System Maintenance



5.6 Practical considerations in managing pH and temperature

In theory, effective control of post mortem pH and temperature decline can provide precise management of meat quality outcomes; in practice, this can be difficult to achieve under commercial conditions. Although the chilling of a carcass can be accurately managed with controlled air temperatures and airflows, there must be significant temperature gradients between the surface and deep tissues of a carcass during the chilling phase (the gradient can be as much as 12°C between surface and deep muscle tissue), and these gradients impose some absolute limits to effective temperature control, particularly so in large beef carcasses.

The second arm of effective processing is controlling pH decline within limits defined by temperature. The effects of electrical stimulation on pH decline can be quite dramatic: for example rigor mortis can be attained in 2 hours in a heavily stimulated carcass, instead of 12-18 hours in an unstimulated one, and careful control of the electrical inputs can generate an intermediate rate of pH decline. Electrical stimulation is therefore a very flexible tool to define a required specification. The role proposed for electrical stimulation is therefore much more sophisticated than simply to prevent cold-induced toughening caused by muscle contractures. It is also important to recognise that electrically-induced effects on muscle pH decline have a range of possible sources: these include electrical stunning, electrical immobilisation, back stiffening during hide pulling and electrical stimulation.

There also exists the risk of excess electrical stimulation. When the rate of pH fall is too great relative to cooling rate, meat proteins are damaged and lose the ability to bind water, leading to high drip losses. Tenderness is also compromised, as is colour stability during retail display, These conditions are usually the result of combining very high levels of electrical stimulation with slow chilling and tend to be more prevalent in beef than lamb processing.

6 Conclusions

The SmartStim system is running effectively. The pH fall is complying with the original targets set up for the system and this is still appropriate given the current chilling specifications.

The meat quality outcomes are highly satisfactory after minimal ageing periods with low levels of variability between carcasses.

The recommendation is that Carne should continue to support the system. This will provide the plant with technical support as required, a bi-annual system evaluation and will ensure that the system continues to be monitored and optimised using the remote access facility. Software and hardware upgrades will be included as part of this support contract.

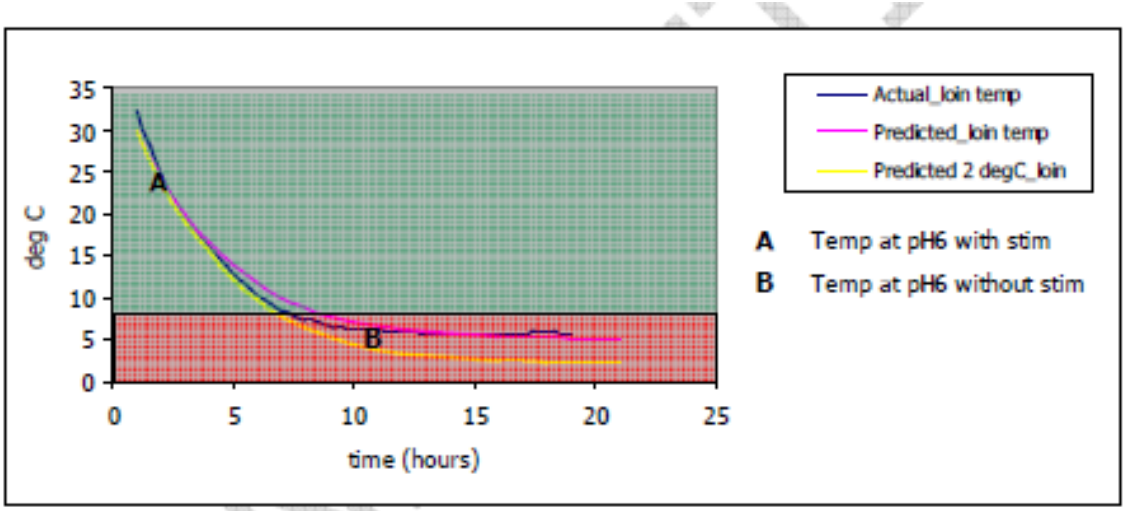
7 Process Recommendations

Chilled export product has a better shelf life with respect to both colour stability and microbial growth if the carcass chilling regime is accelerated. Now that the plant has an operational stimulation system, a faster chilling rate is possible without risk of permanently toughening the product by cold-induced contractions of the muscles (cold shortening).

Without stimulation, the very slow pH declines we measured in the unstimulated carcasses combined with a faster chilling rate would make the real risk of cold shortening very likely.

A faster chill combined with the existing stimulation may result in some reduction in tenderisation during the first few days following slaughter. However, product that is being exported chilled generally has several weeks to tenderise and so there would be no disadvantage to the tenderness of the product in the export markets.

2°C chill option:
The current 5°C chill and the 2°C Tesco chill were evaluated in a predictive lamb tenderness model. The graph below shows three cooling curves :
• Actual temp (current 5°C – blue line) – the mid loin temperature declines as measured with temperature loggers during the meat quality benchmarking exercise.
• Predicted loin temp (pink line); a computer simulation of the current 5°C (based on an average temp throughout the carcass).
• Predicted 2°C loin temp (yellow line); a computer simulation of the 2°C Tesco chill (based on an average temp throughout the carcass).



In summary, the 2°C chill makes little difference to the loin temperature until after approximately 8 hours. After this time, the chilling curves diverge noticeably, and the loin temperature was approximately 3°C less after 10 hours with the 2°C chill.

The convention is that meat temperature must remain above 10°C as long as the pH is 6.0 or above to avoid cold shortening but, in reality the tolerances are significantly greater.

Typically, what is measured when people make claims of cold shortening is meat that is tenderising very slowly due to the fast chill, but this meat will eventually reach a normal tenderness if given long enough to age; whereas, true cold shortened meat is toughened and stays tough even after ageing. True cold shortening is therefore quite hard to generate and is

really only found consistently when the temperature is well below 10°C while the pH is at approximately 6.2.

The pH declines measured in the lamb carcasses were unusually slow, so the loins in some carcasses may fall into this category if stimulation is not used (red area of graph), although the slower cooling in the leg would make this cut acceptable. Even with the current cooling regime, the results from the benchmarking also tend to reflect this: The higher level of purge loss in some of the unstimulated loins is probably caused by a degree of muscle shortening.

While the shortening is not extreme and is clearly not classical cold shortening (as the meat has become tender after 40 days of ageing), it has resulted in some reduction in overall quality.

In summary, the current 5°C chill without stimulation maybe generating some level of shortening in loins where the pH fall is relatively slow, and this will, in turn, result in higher fluid losses and inconsistent tenderness along the loin. This outcome will be more severe if unstimulated carcasses are subjected to the 2°C chill.