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Measuring and communicating the value of meat industry program outcomes

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1. Executive Summary

In 1999, MLA identified poor eating quality of red meat as one of the major industry problems affecting consumer acceptance of red meat. Past estimates had established that approximately 20% of sheep meat failed consumer expectation in eating quality

To address this industry wide problem and to provide innovative solutions to it MLA has initiated the Sheep Meat Eating Quality Program (SMEQ) and the Meat Quality Science and Technology Program (MQST) – Generation 1, or Meat Electronics program. This program was to provide technical intervention solutions to support the SMEQ program.

Research in the past had shown that poor eating quality was mainly due to lack of tenderness. Common causes of toughness were cold and heat shortening, resulting in poor ageing of the meat. Variability in meat tenderness as perceived by the consumer is influenced to a larger extent by processing factors than by both animal and cooking factors (Fig 1), Cold and heat shortening could be prevented by specific processing procedures or by electrical stimulation (ES, see Box 2). The MQST program was to develop practical, safe and effective ES systems that could be installed in commercial plants.

The meat physiology and muscle metabolic parameters defining high quality lamb and sheep meat had been identified by research within the SMEQ Program and other research. The required levels of muscle pH and temperature prior to chilling and freezing and repeatable and consistent achievement of these optimal parameters by using ES were promoted to the processing industry.

Although there were existing technologies in use in the industry, they were not well accepted due to safety concerns for operators and associated risk management costs.

During the Program two new ES technologies were developed that were both safe and effective in eliminating tough sheep meat due to cold and heat shortening:

Technological achievements were:

- A new dose controlled Mid Voltage Electro Stimulation system (MVES)
- A new dose controlled Low Voltage Electro Stimulation system (LVES)
- Electrode systems for both the MVES and the LVES systems
- IP relating to a Computer Process Management System Concept (Patent Application in 2002). The IP is now fully owned by MLA.
- Know-how on systems installation

Commercial achievements were

- Engaging a syndicate of six sheep meat processors within the Plant Initiated Projects Program to act as pilot, test and demonstration plants.
- Licensing of Millers Mechanical Ltd to commecialise the Generation 1 sheep electronics technologies. The company has extensive experience in the sheep meat

processing industry from slaughter to freezing, with past involvement in the inverted dressing process development for sheep in New Zealand.

- Purchasing of 50% share of IP relating to the Generation 1 sheep electronics technology from Applied Sorting Technologies (AST) in Victoria, a company closely involved with the development of the production prototypes, while still retaining the company for the production of the electronics equipment.
- From 2003, both Woolworth and Coles are starting to use sheep meat grading criteria developed within the SMEQ program for specifying their requirements to sheep meat processors. The increased adoption of the ES technology by sheep processors subsequently could be attributed in part to this market pull by the supermarket buyers.
- Exceeding the 2006 targets for commercial installations of sheep electronics already in 2005. In total, seven LVES, 15 MVES and two electro-immobilising systems were installed.
- Anecdotal evidence of reduction in the proportion of lamb with tenderness problems to near zero percent.

Benefits

The benefit of a reduction of sheep meat with low eating quality is seen as benefiting that whole industry. However, the quantification of the benefits should be accomplished within the financial assessment of the SMEQ Program.

Benefits to the consumer are more consistent eating quality. Benefits to the lamb and sheep producer is a higher consumer demand. Processors gain benefits through having market access for their product to the supermarket retail segment.

Recommendations for the future:

To avoid a repeat of the resource intensive Generation 1 commercialization for the planned Generation 2 sheep electronics, the technology or the commercialization process of Generation 1 needs to be analysed.

Technology issues need to be addressed to improve Generation 1 sheep electronics and electrode systems where necessary.

As installations are on target and eating quality problems due to lack of tenderness have decreased to almost zero already, based on anecdotal evidence the MLA effort on active marketing of Generation 1 sheep electronics should be decreased.

To create Generation 2 sheep electronics design concepts that will provide a long lasting benefit to the industry, an identification of all the product, task, operational, information and decision flows in a processing plant should be done prior to the design phase.

To avoid similar resource intensive installations of Generation 2 sheep electronics in the future, a thorough identification of the anticipated product, task, information and decision flows in sheep processing plants needs to <u>precede</u> the design phase of the Generation 2 electronics technologies.

2. The Meat Quality Science and Technology Program (Meat Electronics) – Generation 1

2.1. Context

Meat & Livestock Australia Limited (MLA) is a producer-owned company that provides services to the entire Australian red meat industry including producers, processors, exporters, live exporters and retailers.

MLA's core activities are geared to improve market access, build demand for Australian red meat, and to conduct research and development (R&D) to provide competitive advantages for the industry.

MLA conducts R&D throughout the supply chain to develop metrics on supply and risk for the red meat industry and to provide innovative solutions to industry problems. Research addresses product development, health and safety, education and training, technology development and commercialisation, food safety and microbiological research, and co-product innovations.

Industry wide problem

One of the industry problems has been inconsistent red meat eating quality. Past estimates had established that approximately 20% of lamb and 10% of prime beef failed consumer expectation in eating quality

To address this industry wide problem and to provide innovative solutions to it MLA has initiated a number of programs such as

- The Sheep Meat Eating Quality Program (SMEQ),
- The Meat Standards Australia (MSA) Program, and
- The Meat Quality Science and Technology Program (MQST) – Generation 1, or Meat Electronics program.

When these programs were deployed a number of contributing factors to poor eating quality had already been identified through past Australian and international research. For example it was known that:

- Poor eating quality was mainly due to lack of tenderness,
- Common causes of toughness were cold and heat shortening of the muscle fibres, resulting in poor ageing of the meat (see Box 1),
- Variability in meat tenderness as perceived by the consumer is influenced to a larger extent by processing factors than by both animal and cooking factors (Fig 1),
- Cold and heat shortening could be prevented by specific processing procedures or by electrical stimulation (ES),

- ES technologies had already been researched worldwide and, if used appropriately, had been shown to tenderize meat (Hwang et al, 2003, and Jensen et al 2004)
- The ES equipment that was in commercial use in a small number of plants was perceived to be associated with OH&S risks and therefore expensive to install.
- Sheep meat and beef processor requirements with respect to electronic intervention technologies were different. The existing equipment did not cater for all modern processing requirements in all plants.

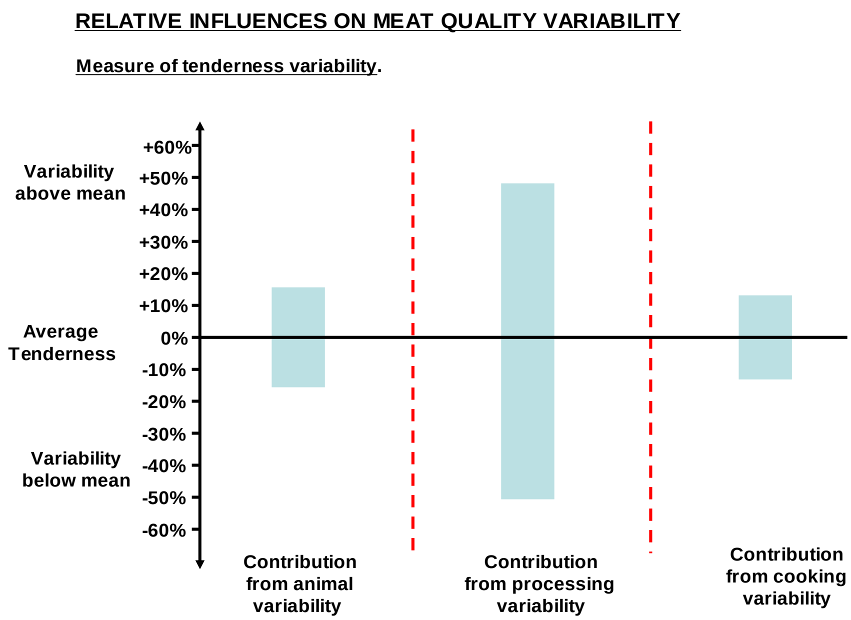

Figure 1: Relative influence of animal, processing and cooking factors on meat quality variability, measured as meat tenderness

The aim of the three programs combined was to provide both beef and sheep meat industries with specific tools and processes that would allow their respective industries to provide consistently tender meat of high eating quality to the market. Benefits are expected to flow to all participants in the red meat value chain from producer to the consumer. MLA is currently facilitating the adoption of the outcomes of these programs.

2.2 Sheep meat industry problem

Consumer issues with poor eating quality of lamb and sheep meat are not new. In the first half of the 1960s complaints about the toughness of NZ lamb became prevalent. At that time the availability of new and highly effective freezing technologies had enabled blast freezing of lamb carcases whilst still slaughter warm. These freezers were so effective that prior chilling was not deemed necessary. Most unexpectedly this resulted in increased toughness of lamb. (Lawrie 1977).

The cause was found to be due to the phenomenon of cold shortening. Similar problems also occurred in Australia at the same time. The phenomenon of cold shortening and other meat quality related problems were extensively investigated over the last three decades by researchers in Australia and New Zealand. Substantial progress has been made during that time in understanding muscle metabolism and the processes involved in turning muscle into meat. The knowledge about many of the critical parameters that determine meat tenderness has increased throughout the meat industry (Figure 2).

One of the outcomes of this research in New Zealand, the United Kingdom, Australia and the USA was that carcases and muscles from a variety of animals could be prevented from experiencing cold and heat shortening by electrical stimulation of individual muscles or whole carcases.

Box 1 How does muscle turn into meat?

For meat to be of acceptable eating quality there has to be an **acceptable pH and temperature decline** during dressing from slaughter to chilling. Both pH and temperature have to decline at an optimal rate, i.e. they have to fall into an **ideal window (Figure 2**). Meat that has experienced an ideal pH and temperature decline will also **age** well as the meat tenderizing enzymes are less likely to become denatured. The cause of the pH decline is the process of anaerobic glycolysis which as an end product has lactic acid.

It has been established that lamb and sheep carcases need to progress through rigor mortis prior to freezing and must not be cooled below 18^0C until they reach pH 6.0. If carcases are frozen at higher pH then **cold shortening** results. Rapid cooling can slow rigor mortis and the decline of muscle pH. The ageing enzymes that tenderize meat over time work more slowly and meat takes a long time to reach an acceptable eating quality. Upon thawing the meat usually is very tough.

The opposite effect, **heat shortening**, occurs if sheep and lamb carcases reach a pH below 6.0 when still at temperatures above 25^0C. However, in contrast to cold shortening, the main effect is a shift to pale watery meat (**PSE-meat**) which will also be down graded. These types of carcases may never age as the ageing enzymes can be denatured.

Both phenomena lead to toughness and reduced eating quality. In sheep meat and especially small lambs, cold shortening is the more common industry problem than heat shortening.

Economic pressures towards faster throughput in processing plants requires that carcases progress through rigor mortis and appropriate pH decline as rapidly as possible without jeopardising meat ageing and eating quality later on.

Electrical Stimulation (ES) of lamb and sheep meat can hasten pH decline and rigor mortis by speeding up glycolysis and thus allowing chilling to take place earlier without negative effects on tenderness.

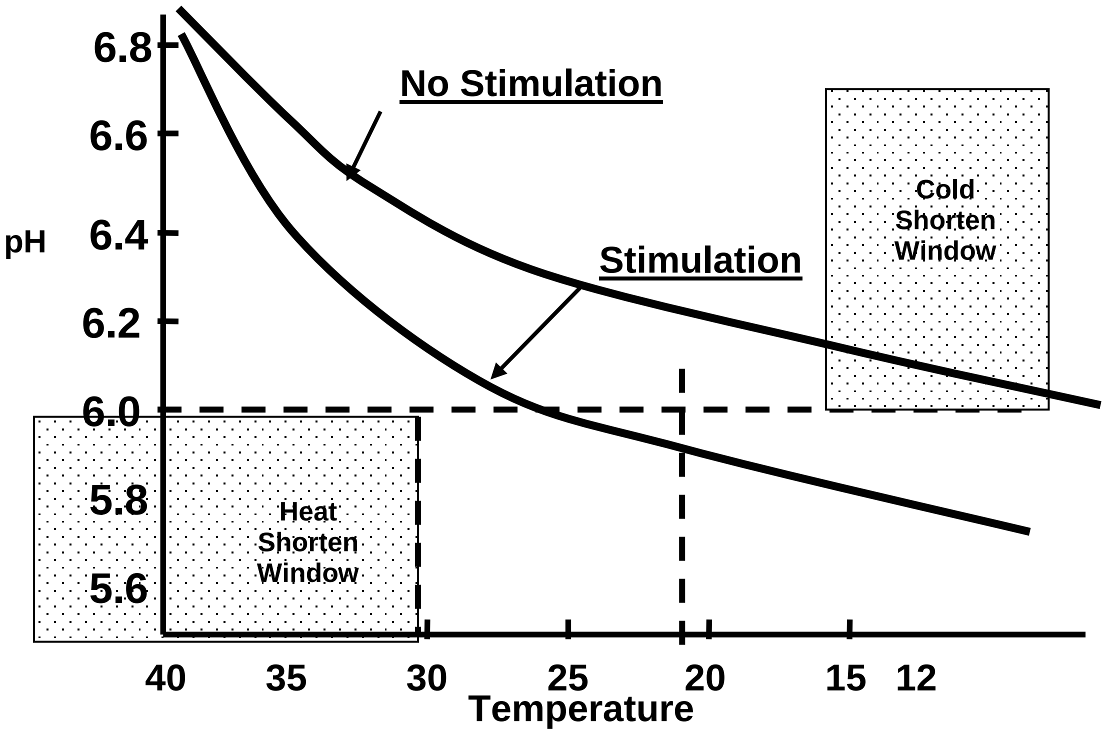

Figure 2: Required pH / Temperature window with and without Electrical Stimulation for sheep/lamb meat to avoid cold and heat shortening. The ideal window is between 15^0c and 25^0C

2.3 Potential Solutions

Potential solutions to the problem were to either

- Promote that relied on achieving correct ph/temperature parameters prior to chilling – without the use of ES,
- Promote better processing practices in conjunction with the installation of ES equipment that was available on the market at the time,
- Develop and commercialise better and safer ES equipment and facilitate its market introduction, supported by promotion of better processing practices.

MLA decided that improvement of existing processing practices without ES was not likely do be sufficient to achieve more consistency in eating quality of lamb and sheep meat. A quick reduction in variability of tenderness was needed and ES was believed to deliver faster results than relying on promotion of new concepts alone.

At the time of deployment of the MQST Program only two sheep meat processors in Australia were using ES equipment. The ES systems were High Voltage stimulators that represented OH&S risks. To recommend adoption and routine use of such equipment throughout the industry was not seen as a viable option.

The third option was seen as the best option and the expected outputs from the SMEQ Program were anticipated to underpin the commercialization effort required to facilitate adoption of ES technology in the market.

Box 2 What is Electrical Stimulation (ES) of meat?

Electrical stimulation (ES) involves the passing of an electric current through an animal carcase after slaughter, causing the muscles to contract. Muscle contraction requires energy and the muscle utilises glycogen in response to the repeated electrical stimuli. The increased rate of anaerobic glocolysis compared to non-stimulated muscle results in the build-up of lactic acid and an immediate fall in muscle pH after ES, followed by a change in the rate of pH fall compared to non-stimulated muscle. This process hastens the process of rigor mortis, a required prerequisite for meat ageing enzymes to effectively tenderize meat.

Electrical parameters such as peak voltage, total electrical energy, type, shape and frequency of pulses, but also time of stimulation after slaughter are important to generate the appropriate ES regime for tenderisation.

Too much electrical energy input can increase glycolysis too much and muscles are damaged to such a degree that PSE meat results.

2.4 Solutions

2.4.1 The Sheep Electronics Program – Generation 1 and its strategy

The Sheep Electronics Program – Generation 1 was to draw on information from the SMEQ Program on processing and consumer requirements. To consistently process sheep meat and lamb without cold and heat shortening ES equipment needed to become a user friendly standard tool of sheep meat processing plants:

The purpose of the program

The purpose of the program was to develop technologies that would:

- Increase meat tenderness/prevent toughness consistently and reliably,
- Increase plant efficiency
- Improve Occupational Health and Safety (OH&S) on the slaughter floor in relation to the operation of the equipment and sheep.

Program strategy

The program strategy was to

- Conduct R&D on dose controlled meat electronics technologies that interact with the carcase,
- Develop robust meat electronics technologies to the industrial prototype stage,
- Protect appropriate IP,
- Test and trial the technologies in commercial processing plants through the Partners in Innovation Program (PIP),
- Promote benefits of the technologies to the appropriate market segments in conjunction with the SMEQ Program,
- Commercialise the technologies through a commercial company (commercialiser),
- Facilitate adoption by the processing industry.

2.4.2 Available knowledge about ES at the beginning of the Sheep Electronics Program – Generation 1

In 1998, there was substantial knowledge available about ES. The application of ES in the red meat processing industries was not new anymore but developments had been quite erratic around the world. This was to a large degree due to the existence of significant gaps in the body of knowledge on how to apply and optimise the technology.

Although ES for the purpose of hastening rigor mortis, ageing and saving on refrigeration cost had been originally developed in the 1940s with patents issued in 1951 (Table 1), commercial exploitation of this IP never happened. Only the pressing issue of cold shortening in lamb led to active pursuit of ES as a means to an end – tenderizing lamb and sheep meat, first in New Zealand and then in Australia.

The development of inverted dressing of sheep in New Zealand where sheep are hitched to the dressing rails by four instead of only two legs allowed the use of low voltage stimulation (LVES) early after bleeding. The additional practice of enhancing efficiency of bleeding through a thoracic stick allowed improved blood recovery through low voltage stimulation at the bleed rail, which also stimulated the meat.

In Australia, where inverted dressing is not as common (only a few establishments use it), only two establishments had high voltage (HVES) equipment in use.

Although most countries involved in good meat science have been working on ES as a means of understanding meat physiology, New Zealand has been at the forefront, with Australia, USA and Great Britain not far behind. Research in the USA focused on beef A myriad of scientific articles had provided results of experiments on ES but as the use of ES was mainly for the purpose of establishing the mechanisms of rigor mortis or other muscle metabolic processes, there was no consistency in the experimental electrical parameters used, leading often to contradictory results and interpretations. Additionally researchers used a variety of muscles, breeds, species and experimental designs.

It is therefore not surprising that the knowledge of the mechanisms of action of ES (high voltage, mid, and low voltage, pulse frequency and width and other parameters) was still very sketchy, especially in the early days of ES. When the Sheep Electronics Program began, the mechanisms of ES on the muscle were still not clear.

There also existed evidence that muscles could be damaged by for example applying too much current, for too long time, or at a too high pulse width. Muscles then appeared “cooked” or showed PSE signs.

In the more recent research focus has shifted more to the ultra structural protein and enzymatic systems of the muscle and there is still no complete understanding on how to completely control the glycolytic process in all individual animals with ES or to prevent adverse effects of the inappropriate application of ES.

However, ES had been used commercially with success in New Zealand with sheep and in Australia, New Zealand, the US and also other countries for beef.

It was initially thought that a functioning nervous system was needed to utilize low voltage to stimulate the meat. It was expected that lower voltages could be used at the beginning of dressing because less energy was needed to stimulate the nerves. However, in sheep low voltage ES trials were not very successful as electrode systems were not developed far enough to enable consistent and effective contact and stimulation of wooly sheep shortly after slaughter. Therefore high voltage ES systems were developed which stimulated the carcases at the end of dressing and before chilling. It was believed that the nervous system by then was no longer responsive to electrical inputs, and therefore high voltage systems were required.

A problem with these original HV stimulators was that they used a constant voltage to stimulate the carcase. A constant voltage produces a varying current through the carcase due to variations in contact resistance and different carcase resistance. This, in turn, led to animals of different types and sizes receiving either more or less stimulation with a varying tenderising effect. It was found that this type of stimulation led to unpredictable outcomes.

Many plants chose not to use the HV equipment due to the potential danger of electrocution of operators and the expense of having to build dedicated room or cabinet to make the process safe.

Expected outcomes of the Sheep Electronics Program Generation 1

There was no debate at the beginning of the Sheep Electronics Program that ES works and if applied correctly would reduce the variation in tenderness in a batch of sheep or lambs and allow chilling earlier. Variation in the rate of pH decline is expected to be reduced and especially smaller carcases no longer should be tough especially due to cold shortening.

Consistency in tenderness and high meat eating quality was expected to increase.

Year	Development	Reference
1749	Benjamin Franklin electrocuted turkeys, with the result that they were ‘uncommonly tender’.	Devine et al 2004
1922	Observation that muscles contract on quick freezing but cause could not be explained.	Locker and Hagyard 1963
1940s	Work in the US by Harsham and Deatheridge (Kroger Corporation) with Rentschler (Westinghouse Electric Corporation) on tenderizing beef through ES. Initial provisional application for the process of tenderising meat filed in 1945. A number of voltages from 40 to 3000V were trialled and also different frequencies.	US Patent 2,544,681 US Patent 2,544,724
1951	In 1951 two patents filed on both the ES equipment(High voltage) and the process of tenderising meat. The intention was to hasten the ageing process and save on cost of refrigeration and storage equipment. The utility for use in lamb and mutton is mentioned. The ES equipment patent is for a High voltage system. No commercial exploitation of the IP followed.	US Patent 2,544,681 US Patent 2,544,724
1960s	Complaints about lack of tenderness in lamb in NZ and Australia on the rise. Rapid freezing of slaughter warm carcases found to be the cause. Connection made between chilling, cold shortening and eating quality.	Lawrie 1977 Locker and Hagyard 1963
1960	Research on the role of ATP in rigor mortis.	Bendall 1960
1970s	Established that glycolysis is faster at 37^{0}C than at ambient temperature Research in NZ, Australia, UK and the US focuses on the effect of ES on glycolysis, heat shortening, cold shortening and on the ultrastructure of muscle after ES. Established that cold shortening and heat shortening can be avoided if cooling takes into consideration pH and carcase temperature	Lawrie 1977
1970s	Research on the effect of a variety of electrical stimulation parameters and their combinations in relation to rigor mortis, muscle metabolism and physiology, and on tenderness results in the emergence of commercial ES equipment first in New Zealand, followed by Australia and the US (High Voltage equipment)	Variety of literature and internet sources
Late 1970s	New Zealand develops inverted dressing procedure for sheep which provides benefits for ES	Inverted dressing Review 1997
1980s	Debate whether a functional nervous system is needed for ES. Research at CSIRO shows that a functional nervous system is necessary for low voltage ES to be effective but not necessary for High Voltage ES. Later it was shown Mid Voltage stimulation is effective at the end of the dressing process	Morton et al 1982
1990s	Research focuses on meat ultra structure, muscle proteins and enzyme systems	Hwang et al 2003, Devine et al 2004
1990s	From 1992 to 1995 Australia Meat Holdings develops a variety of ES equipment for beef in conjunction with Applied Sorting Technologies in Victoria and Food Science Australia (CSIRO)	MLA

Table 1 Key developments relevant to sheep meat processing utilising ES

2.5 Key Developments of the Sheep Electronics Program

2.5.1 Technical Developments

At the beginning of the program Ian Richard joined the MLA as Manager Technology Development and leader of the MQST program. He had a background in electrical engineering and had been the R&D Manager of Australia Meat Holdings, Australia's largest beef processor. From 1992-1995, in this role he had developed a new dose controlled Low Voltage stimulation system for beef and a number of other electronic intervention technologies.

Applied Sorting Technologies, a Victorian company which developed X-ray equipment for the food industry to discover contaminants in packaged goods such as meat cartons. AST was closely involved with the engineering of the AMH developments and they had built the commercial versions of the ES prototypes.

To develop better and safer equipment for sheep carcase stimulation three avenues were pursued:

- A new controlled dose Mid Voltage (MVES) system for the post-dressing area to control meat tenderness instead of the dangerous High Voltage systems on the market,
- A new controlled dose Low Voltage (LVES) system for installation in the bleed area to control meat tenderness,
- The development of a Computer Process Management System concept (CPMS Concept) that in the future would ultimately allow the development, integration and central control of all electrical stimulation systems in a plant based on data inputs related to animal and carcase parameters prior to and after ES.

The design of both, the Mid and Low Voltage systems needed to ensure that each stimulation system could be used as a programmable stand alone unit, so that ES of batches of animals could be dose controlled. The design should ensure that stimulation systems would not be made redundant by a future CPMS, i.e. compatibility with a future CPMS needed to be part of the design concept.

Alongside the design of the ES systems appropriate electrode systems needed to be developed also.

An electrical immobiliser as used for beef was initially not thought to be important for sheep as they were not large enough to cause substantial injury by involuntary kicking after killing. An electrical immobiliser disables the nerves sufficiently to prevent involuntary carcase movement. Mechanical layout of many plants did not allow their installation except in a very small number of plants where an immobiliser could prevent sheep from falling off conveyors prior to hoisting. Benefits from an immobiliser in such cases would derive from a potential reduction in injuries resulting from lifting carcases back on the conveyor.

The Computer Process Management System (CPMS)

It was decided to first focus on the design of the Mid and Low Voltage systems for sheep.

As most sheep processors were expected to use only one ES system, either a Mid or a Low Voltage system, rather than multiple electrical inputs along the processing chain as in beef processing, carcase over-stimulation was not expected to become an issue limiting adoption.

Research on animal characteristics such as those used in Meat Standards Australia (MSA) or Sheep Meat Eating Quality (SMEQ) grading needed to provide more information first so that the CPMS data processor could be calibrated first and in return prescribe the right amount of electrical energy to batched or even individual carcases. It was envisaged that this equipment would prevent potential over-stimulation of carcases.

In 2002 MLA took out a patent on the business method of using a Computer Process Management System Concept (CPMS Concept) that regulates the operation of the individual ES components via operator defined parameters and interaction with the individual component computers inside each of the electronic technologies.

The Mid Voltage System (MVES)

The rationale behind developing a Mid Voltage system was that new research by MLA had revealed that pulses with 1/100th of the energy normally used with High Voltage stimulation post dressing had the same tenderizing effect as High Voltage stimulation. Therefore a MVES prototype for sheep which also proved to be safer, cheaper and much easier to install than the HVES equipment on the market. It did not pose any electrocution risks to operators and did not require special cabinets to house the stimulation equipment.

The new MVES system could deliver controlled doses of electrical energy and it was designed to be compatible with a future CPMS.

The development of the MVES system for sheep was a major technical success but not all plants (only 30%) had sufficient room to incorporate the new Mid Voltage system post dressing and therefore a better LVES system was also needed for plants that could not fit an MVES system at the end of the processing chain.

The Low Voltage System (LVES)

In trying to design an effective sheep LVES system for the bleed area similar to the beef equipment it became clear that it was not only necessary to design a controlled dose stimulation unit but also to design and develop appropriate sheep electrodes.

Wool is a good insulator and sheep legs do not have much surface area to allow good contact with an electrode, even without wool. Sheep processing chains run at high speed at up to 10/minute and each sheep needs to be stimulated for at least 30 seconds. To achieve an appropriate stimulation effect from LV stimulation, both good electrode contact through the wool and sufficient contact time was required.

Additionally, plant layout varied between processing plants, and it became obvious that individual plants might need specific electrode developments to achieve effectiveness of LV stimulation in all plants.

2.5.2 Technical achievements

The first prototypes of dose controlled CPMS concept compatible versions of the sheep LVES and MVES electronics were built and tested in 2000 and commercial prototypes were available by 2001.

Commercial versions of both types are now installed in processing plants throughout Australia and adoption of these systems has been better than expected.

The challenge of developing electrodes for LV stimulation for woolly sheep, was almost unsurmountable. However, the development team are now hoping that after six years of work the most recent development of serial knife-edge multi blade electrodes will enable plants that currently do not have the room to adopt systems of transverse leg electrodes to use LV systems. These new multi-blade electrodes part the wool on the sides of individual sheep as they move along the chain and one or some of them will make sufficient skin contact to result in sufficient stimulation for tenderisation.

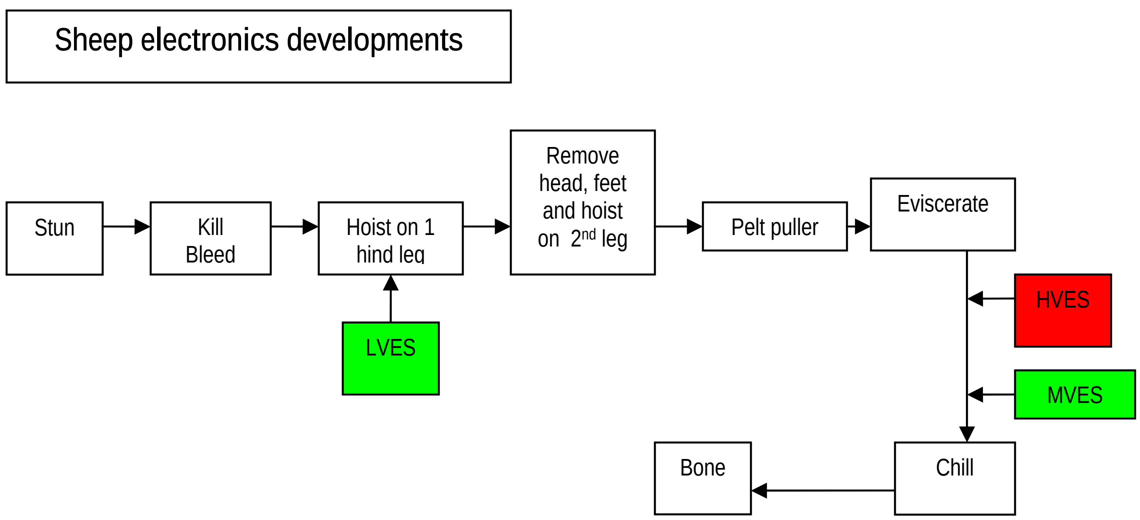

Figure 3: Technical Achievements of the Sheep Electronics Program.
<u>Green Boxes</u>: New developments. <u>Red box:</u> Original High Voltage Systems in use in the industry

2.5.3 Commercial Developments

In 2000 there was no easy way of deploying ES developments to most sheep plants in Australia. MLA promoted the idea of developing dose controlled ES equipment for sheep to six commercial sheep plants. Within the Plant Initiated Projects Program (PIP) the syndicate of these six sheep processing plants installed the initial production prototypes as pilot installations.

In 2001, most of the electronics developments compatible with the CPMS concept were at a production prototype stage that was convincing enough for MLA to make a decision to commercialise the technologies and encourage adoption by the meat processing industry.

In line with the program strategy and adoption plan, which had been updated in 2001, the decision was made to call for tenders from firms that had suitable experience in the industry and were capable of marketing and supporting commercial ES installations in Australia.

Australian Sorting Technologies (AST) had become a major partner in the development projects in 2000 and had entered into an agreement with MLA to provide and license the background IP to MLA for the purpose of the sheep electronics project, resulting in an equal share of the resulting meat electronics IP. In 2005 MLA purchased the AST owned IP component and now fully owns all Generation 1 sheep electronics IP.

The tender process eliminated a number of tenders and Millers Mechanical (NZ) Ltd was chosen and given an exclusive license to commercialise the Generation 1 Sheep Electronics. The reason for choosing this firm was their extensive experience in the meat processing industry throughout the processing chain from slaughter to refrigeration.

Millers Mechanical is a part of the Realcold Group of Companies which also includes its Australian Division, Realcold Milmech Pty Ltd in Queensland. Millers Mechanical had extensive expertise in the design and manufacture of MILMECH abattoir systems, equipment, materials handling and refrigeration in the meat processing industries, and had also been involved in developing the inverted sheep dressing process and Shiny Robot Venture in NZ. Realcold Milmech's core business is the supply of meat processing systems, low temperature freezing systems and other meat processing equipment in Australia.

Since 2002, Realcold Milmech had been involved in the production prototype testing of the sheep electronics systems in commercial plants.

Millers Mechanical and MLA signed the licensing document that outlined the objectives of the commecialisation.

Millers started marketing the new technologies immediately but installations were initially slow to follow.

The experimental prototypes had worked well in the pilot installations but each processing plant had a different set-up. Some could not fit the equipment in as there was no room or they needed to make structural and mechanical changes to incorporate it into their layout.

Managing the installations proved to be a very time-consuming task. Realcold Milmech had been expected to do the installations mainly by themselves but this proved to be not cost-effective due to the time involved in site visits, engineering changes, and consequently Ian Richards needed to still spend a lot of time the technology at each site (Box 3).

Box 3 Processor technology adoption cycle

The following is a list of tasks that are typical of an installation:

- Promoting the technologies to processing plants.
- Designing variations to the electrode systems to match plant requirements
- Supervising construction and installation of equipment.
- Commissioning equipment.
- Performance testing.
- Reporting and interpreting performance data to plant personnel

Support of the ES technology in the market is time and resource consuming as the Generation 1 technologies cannot be just “bought out of the crate” and installed with local contractor knowledge alone.

In 2004, Miller’s Paul Keane took on the project adding exceptional skills in engineering design, project management and getting the buy-in from processors. This has ensured that the project began moving along at faster speed.

The costs for sheep installations can be quite high if several electronic stimulation units are required due to the high speeds of the sheep processing chains in some plants (up to 10 sheep per minute).

Typical approximate installation costs are:

- LVES for stimulating sheep: $50,000 to 120,000, depending on layout and number of stimulation units and type of electrode system required,
- MVES for stimulating sheep: $50,000,
- A sheep installation including immobiliser as for cattle in suitably laid out plants may cost up to $200,000.

From 2002 onwards, the retail sector and especially the major supermarket chains were supplied with information about the compelling benefits of adopting SMEQ meat quality grading criteria. The benefits of using ES for ensuring a high consistent eating quality of sheep meat were also promoted to the retail sector by both MLA and Realcold Milmech.

Increasing the pace

The first commercial installation of an ES system for sheep was completed in November 2003.

In January 2005 the MLA innovation adoption plan for the MQST – Generation 1 Program was updated. Benefits from Generation 1 technologies (for both beef and sheep meat) were estimated to be $175 million over five years of which 68% of the benefit was estimated to flow back to the producers. By January the uptake of the technologies had not substantially progressed beyond the original pilot demonstration plants that had been part of the development.

In line with this plan a list of 60 beef and sheep processors were selected which represented approximately 80% of the national red meat production for both domestic and export use. This list was now targeted as a matter of priority to increase speed of adoption with a combined Millers and MLA effort.

The plan envisaged installation of 16 stimulation systems and one specially developed high frequency electro-immobilising unit by the end of 2005, and a total of 20 stimulation systems and by the end of 2006.

2.5.4 Commercial achievements

From January to June 2005 installations followed at a rapid rate and at the end of June installations were ahead of schedule and target (Table 2)

	Stimulation		Immobilisation
	LVES	MVES	
2004	2	4	
2005	3	7	1
2006	1	3	
Total planned to 2006	**6**	**14**	**1**
Total achieved by end 2005	**7**	**15**	**2**

Table 2 Installations for sheep – planned vs. installed

From 2003 onwards, first Woolworth and shortly thereafter also Coles started to adopt SMEQ grading criteria and thus the requirements of electrical stimulation of sheep meat, and especially lamb. The sheep meat processing industry was quick to recognise the need for installing ES systems. The increase in the adoption of the systems in the last twelve months can therefore be attributed to the combined effort of pull and push commercialisation strategies and effort.

The data developed within the SMEQ program and the concurrent development of the electronics technologies allowed the retail sector to express market pull, and without the knowledge of Realcold Milmech and MLA in electronics and meat processing technology, it is doubtful that sheep processing plants would have been able to complete installations at the recently shown pace.

As a consequence the proportion of poor eating quality sheep meat has decreased from approximately 20% to almost 0% in some recently sampled plants (MLA 2005).

The key developments and achievements of the program are listed in Table 3.

Table 3 Key Developments of the Sheep Electronics Program

Year	Developments
1990	Only two sheep plants in Australia with ES equipment. They were High Voltage units that were used on the carcase after dressing. Most other plants were not suited to install units such as these due to OH&S and cost implications.
1998	In 1998 MLA decision to deploy MQST Program and to develop safer, cost effective lower voltage technology.
1999	Decision to develop individual ES units with their own individual programmable processors to control voltage, pulse type and frequency. It was envisioned that in the future these units could be coordinated from a central processing unit that controlled the whole plant.
1999	Both Low Voltage and Mid-Voltage ES prototype for sheep developed and tested
1999	Work on development of electrode system for pelt-on sheep Low Voltage systems continues until the end of the program to allow stimulation of individual pelt-on sheep in high-speed chains.
2000	Both Low and Mid-voltage production prototype installed and tested.
2001	Program adoption strategy updated. Decision to engage a commercialiser for the technologies.
2002	Patent application filed for CPMS business concept, titled "Electrical treatment of carcases". IP jointly owned by Applied Sorting Technologies (ATS) and MLA.
2002	Millers Mechanical Limited engaged as the exclusive commercialiser of the Generation 1 Sheep Electronics technologies.
2002	Both Low and Mid-voltage production versions installed in selected plants. The majority are mid-voltage units. Due to space constraints in some plants Low Voltage units needed to be installed. Six selected sheep processors agree to install the technology in conjunction with the Plant Initiated Projects Program.
2002	Millers Mechanical licensed to commercialise the Generation 1 Sheep electronics with the agreement of the MLA Board and AST.
2003	Woolworth starts adopting SMEQ specifications and recognises that ES of all their lamb meat is beneficial. Coles follows shortly after and sheep processors are starting to experience market pull demand for the technology.
2003	November 2003 first complete commercial installation.
2004	Adoption still slow. Support of pilot installations stepped up by Millers and MLA.
2005	In January target set for implementation in processing plants: five Low Voltage systems, 10 Mid Voltage systems, and in a plant with a set-up similar to NZ plant operation and layout also a high frequency electrical immobiliser (as in beef).
2005	Installation targets met Eating quality targets met with reduction of tough lamb and sheep meat to close to zero %
2005	MLA buy-out of all ATS owned IP. MLA now owns 100% of all generation 1 sheep electronics IP

2.6 Collaborators

A big program such as this one needed a lot of collaboration and goodwill from other parties for the development, manufacture and testing of prototypes and especially commercial installation in processing plants.

AST was involved as a partner with the electronics development towards robust prototypes at the commercial prototype stage. Local contractors were used to effect the necessary mechanical changes in the plants to accommodate the electronics.

The six sheep processing plants, by utilising the Plant Initiated Project Program (PIP) were instrumental in pilot testing the production pilot systems under commercial conditions. These plants were subsequently making their systems available to the industry as demonstration plants.

The six plants using the commercial prototypes for demonstration are: Colac, Swan Hill, T&R, WAMMCO, V&V Walsh, and Fletchers Dubbo.

A number of research organisations and their staff were supplying the meat science knowledge as input into the design of systems, such as the Dept of Agriculture in NSW and Victoria, CSIRO Meat Science Australia, Murdoch University, the Sheep CRC, and other organisations.

Close collaboration with AgResearch, MIRINZ and Meat and Wool New Zealand (MWNZ) was also sustained over the years.

The MLA SMEQ Program which was initially managed by the LPI Business Unit provided the collaborative framework for the Generation 1 Sheep Electronics technologies. The MLA Consumer Marketing team also supported the development of consumer demand and customer pull through for the technology through their key account managers for Woolworth and Coles.

Millers Mechanical Ltd and its Australian Division Realcold Milmech Pty Ltd have been responsible for most of the commercialisation effort and pre- and post-implementation plant support.

2.7 Benefits

Benefits of the sheep electronics Generation 1 technologies are consistently improved eating quality and tenderness of domestic lamb and sheep meat table cuts derived from stimulated sheep and lamb carcases.

Feedback from retailers has shown that tough lamb in some recently sampled plants has been reduced to almost zero % (MLA 2005).

As there are other lamb meat improvement initiatives in place such as the genetic improvement of lambs, the development of a specialist prime lamb finishing industry and the SMEQ program, the rise in domestic lamb consumption to the sheep electronics program cannot realistically be attributed to the Sheep Electronics – Generation 1 program.

The program has contributed to the general improvement of lamb and meat quality – together with especially the SMEQ program. It would appear to make sense to summarise the benefits of the Sheep Electronics program to the whole sheep meat industry under the benefits of the SMEQ program, with the costs of the sheep electronics program Generation 1 being added in with the SMEQ program cost component.

However, to quantify the proportional share of these benefits flowing back to the various segments of the sheep meat value chain is very difficult (Figure 4 and Appendix).

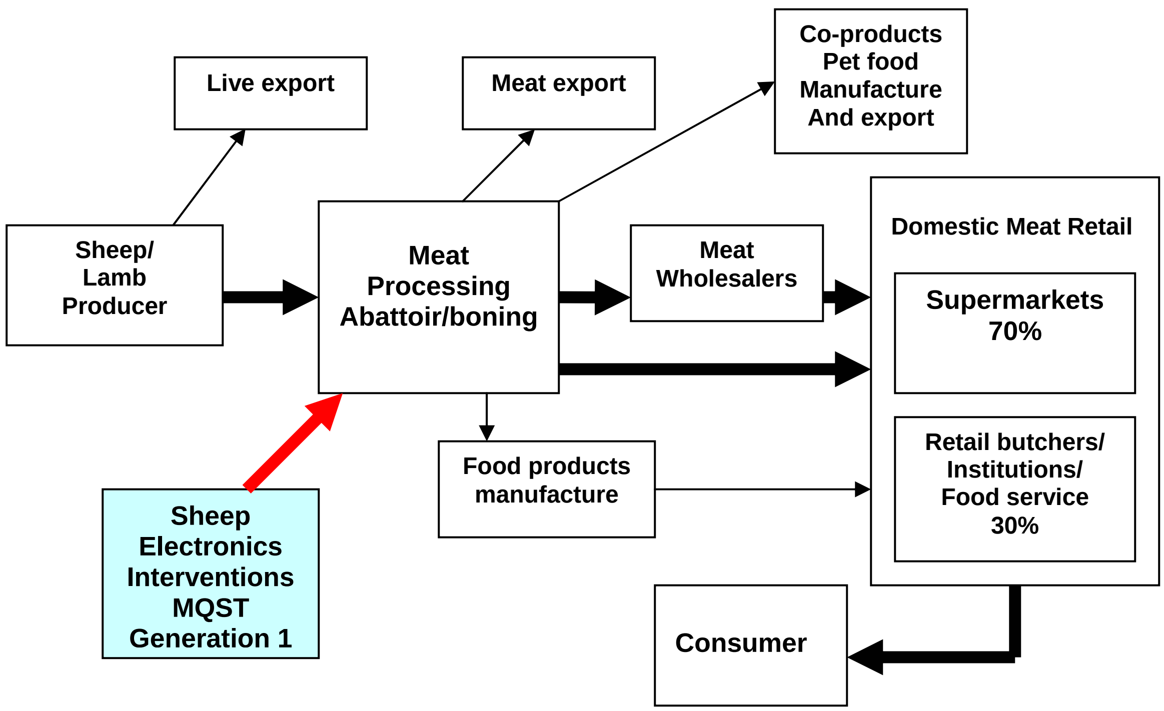

Figure 4 The sheep meat value chain.

The major benefit to the sheep meat industry is most likely that lack of eating quality issues with sheep and lamb meat is facilitating an increase in lamb consumption, and therefore a more consistent demand. The benefits from consistent demand flow back to all segments of the sheep meat value chain.

The main direct benefits of the sheep electronics Generation 1 Technologies will flow to the sheep meat processors in response to market pull. Installation of ES systems as part of a business risk management strategy is expected to deliver the benefit of staying in business and not being by-passed especially by the major supermarket chains.

Benefits of delivering quality guaranteed correctly processed and chilled lamb to the domestic and also the international market is a competitive advantage. There appears to be a possibility that processors could take advantage of a trend towards five-day chilled and air freighted lamb to emerging international markets. This would also require that lambs be subjected to ES to prevent cold shortening.

3 Where to from here?

The Sheep Electronics Program – Generation 1 - can be seen as a substantial success for MLA and the commercialiser. Installations so far have achieved the set targets and are ahead of schedule.

However, it appears that the time and effort required to install a system in sheep plants is very high and probably not cost effective for Millers Mechanical, mainly due to the individual plant layouts which require individual adjustments to the ES equipment and electrode configurations.

Recommendation for improvements:

As the target of sheep installations has been achieved already and the proportion of lamb with tenderness faults, based on anecdotal evidence, has decreased to almost zero %, neither MLA or the commercialiser should spend much additional effort on actively marketing the technologies to sheep processors.

However, to make the sheep electronics – Generation 1 installations a “fool proof” and “out of the crate” effort for establishments that in future want to install the Generation 1 technologies, an analysis of past installations by MLA and Millers should be done. This could lead to identification of specific issues that often or always lead to an unexpected increase of time and resources invested.

An analysis might discover which of the issues are technology issues, and which ones are operational issues or even knowledge issues that could be addressed by better information flow.

If there are specific technical issues that make installations or operation difficult and outcome unpredictable, they need to be addressed. Likewise, specific issues relating to the commercialization process could then be improved and benefits from a sharpened commercialization process will in future benefit other programs and projects

To avoid similar resource intensive installations of Generation 2 sheep electronics in the future, a thorough identification of the anticipated product, task, information and decision flows in sheep processing plants needs to precede the design phase of the Generation 2 electronics technologies.

4 References

Bendall, J.R. (1960): The structure and function of muscle. *In Pharmacology and Disease Ed GH Bourne Vol 2, p.227 Acad Press NY*

Davenport, S. (2000): The Shiny Robot Venture. *In Cases in Strategic Management, Ed G. Hubbard*

Devine, C.E., Hopkins, D.L, Hwang, I.H., Ferguson, D.M. and Richards, I. (2004): Electrical Stimulation. *In Encyclopedia of Meat Sciences Ed WK Jensen, D.Cevine and M Dikeman, Vol 1, 412-423*

Foundation for Research, Science and Technology, NZ (1997): The benefits of meat research in New Zealand: Inverted Dressing Review

Hwang, I.H, Devine, C.E. and Hopkins, D.L. (2003): The biochemical and physical effects of electrical stimulation on beef and sheep meat tenderness. *Meat Sci* 65: 677-691

Lawrie, R.A. (1977): Meat: Current developments and future status. *Meat Sci 1:* 1-13

Locker R.H. and Hagyard, CJ (1963): Cold shortening effect in beef muscles. *J. Sci. Food. Agric. 14:* 787-793

Meat Processing in Australia C2111, IBISWorld Industry Report 8 June 2005

Meat Quality Science and Technology – Generation 1, Industry Adoption Plans, MLA internal document January 2005

Meat Wholesaling in Australia F4711, IBISWorld Industry Report 18 April 2005

MLA Industry Program Plans 2004-05 – 2006-07. Progress Report July to December 2004

MLA Market Information 2005: Australian cattle and sheep industry projections

Morton, H.C. and Newbold (1982): Pathways of high and low voltage electrical stimulation in sheep carcases. *Meat Sci 7:* 285-297

New Generation Process Innovation Programs Outcomes Report 03-04, MLA Internal document

Sheep and lamb dressing. Meat Technology Update December 2001. Food Science Australia

5 Appendix The Sheep Meat Industry Value Chain

Table 4 shows that the Australian sheep meat industry provides 13% of meat processed by meat processors (beef and veal, sheep and lamb meat, and pork. Poultry is not included).

Product/Services	Share
Beef and veal	73%
Sheep meats	13%
Pork	14%

Table 4 Major meat market share segments (IBISWorld 2005)

Domestic meat consumption in Australia has been declining since the end of World War II. Over the last decade meat consumption has somewhat stabilized but consumers demand more variety in meat and are buying more poultry, pork and fish (Figure 5) at the expense especially of lamb and mutton.

However, aaccording to MLA (2005) Domestic consumption of lamb has increased over the last six years. Total expenditure on lamb rose 4% in 2004 with prices up by 5%. Lamb retail prices over the past five years have risen sharply relative to other meats, with lamb prices lifting by 60%, beef by 38%, pork by 25% and chicken by 12%.

Aggressive marketing of red meat and lamb as a healthy meat appears to have halted the downwards trend, in conjunction with the SMEQ program and similar activities such as the MSA program for beef.

It is not clear whether and to what degree an increase in lamb consumption might lead to a cannibalisation of the beef market sector instead of taking market share from poultry and pork. Should that occur the investment benefit of the MQST Program for MLA and its stakeholders would be reduced.

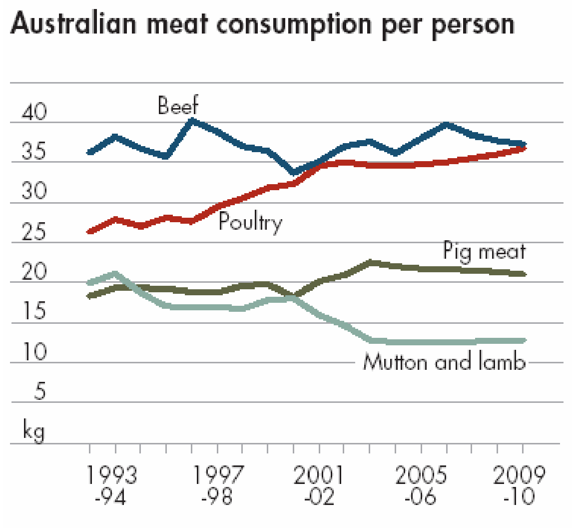

Figure 5 ABARE Commodities 2005 March

The outlook for the sheep meat industry is favourable in the medium term (Table 5) as domestic consumption has stopped declining, export markets are aggressively pursued and growing, especially for lamb meat. The consequences of BSE in Europe, North America and Japan can also be utilized in the short to medium term to establish new customers for sheep meats.

	Unit	2002 -03	2003 -4	2004 -05	2005 -06 z	2006 -07 z	2007 -08 z	2008 -09 z	2009 -10 z
Sheep and lamb numbers	million	106.16	99.25	102.62	105.50	108.2	110.00	111.00	111.30
Slaughterings - Sheep - Lambs	'000	 14,880 17,092	 10,521 16,430	 11,050 116,700	 11,550 17,850	 12,150 19,050	 12,650 12,100	 12,850 120,900	 13,050 21,400
Production c - Mutton - Lamb	kt	 297 338	 214 330	 230 342	 245 375	 255 410	 265 440	 270 460	 275 475
Exports - Mutton c - lamb c	Kt	 218 116	 150 123	 170 131	 182 150	 193 170	 204 185	 208 198	 212 207
Live sheep	'000	6,138	4,748	3,370	3,700	4,200	4,700	5,100	5,300
Consumption per person -Mutton - lamb	Kg	 4.0 11.3	 3.2 10.4	 3.1 10.5	 3.0 11.0	 3.0 11.7	 3.0 12.2	 2.9 12.5	 2.9 12.7
Domestic consumption - Mutton - Lamb	kt	 79 222	 63 207	 62 210	 61 224	 61 240	 62 253	 62 262	 62 269

C Carcase weight, z forecast Source: MLA Australian cattle and sheep industry projections 2005)

Table 5: Situation and outlook for the Australian sheep industry

Industry segments

The major segments of the sheep meat value chain are listed below. Figure 4 depicts the sheep meat value chain, with the thicker arrows showing the flow of that portion of domestic sheep/lamb meat that the consumer can buy at retail outlets. The red arrow shows to which stage of the value chain the Sheep Electronics Program technologies are targeted.

All participants of the sheep meat value chain depend on the skill and integrity of their suppliers to provide a quality product. Value can be added along the supply chain up to the end customer, the consumer of the meat. However, value can also be lost along the way by inappropriate handling and processing at each stage. As each animal and each carcase provides many meals any value lost at the animal and carcase stage will affect many consumers and their perceptions about meat quality.

Not much can be done beyond the processor's door to improve meat quality defects, regardless of their point of origin.

Any quality problems are able to affect a large buyer segment and even larger numbers of consumers

All segments of the value chain are increasingly putting their effort into prevention of problems and management of their supplier relationships with the aim of providing consistent and high quality products to their customers

Primary production - sheep and lamb producers
Since the early 1990s, international demand for sheep meats has grown while the number of sheep and lambs available for slaughter has fallen leading to a recovery of mutton and lamb prices. Recent production trends have led towards more prime lamb production as profitability of the wool enterprise has fallen since the early 1990s. As with beef, there is also an increased trend to sell over the hooks, now 50% of lambs and 14% of adult sheep.

Live export
Live export mostly to the Middle East is mainly serviced by WA, SA and Victoria. These supply chains have developed a specialised industry to supply large lean male sheep for this market.

Meat processing
Sheep and lambs are purchased, slaughtered and processed into fresh, chilled and frozen bone-in and boned out products, manufacturing meat and into co-products. Meat represents 89% of the value of production, co-products such as skins, offal and meat and bone meal represent 11% of the value of production. Meat processors sell their products both domestically and into export markets. Around 70% of mutton production and 35% of lamb production is exported. It is expected that the proportion of lamb export will rise to over 40% in 2005 (MLA 2005).
The USA is the largest export market for sheep meat and accounts for 40-50% of the total value derived from lamb production. Lamb exports to Asia have also been increasing over the past six years.

Due to forward vertical integration meat processors sell approximately 50% of their domestic output directly to supermarkets and 50% to meat wholesalers, i.e. they are themselves wholesaling.

Food products manufacturing
This segment utilizes manufacturing meat such as mutton and other animal by-products for value added food products such as frozen dinners, sausages, pies and other smallgoods.

Wholesale
This segment mainly sells meat from processors to retail outlets and the food service outlets. Wholesalers are a declining force in the value chain as their buying power is steadily decreasing due to the increasing power of the supermarket chains and forward vertical integration of some of the largest meat processors.

Domestic retail
This segment includes supermarkets, retail butchers, the food service industry such as hotels, restaurants and organisational food service outlets (hospitals, military etc).
Consolidation in the retail sector towards giant supermarket chains has led to a factual duopoly of the two major chains in Australia, Woolworth and Coles. Supermarket chains absorb approximately 70% of the meat for domestic consumption and therefore have enormous power over processors and their viability. Their buying power exerts considerable downward pressure on prices that processors pay to producers.

Retail butchers have declined in numbers over the last decade but this trend seems to have bottomed out, with specialist butchers servicing retail customers who prefer to purchase from butchers. A more varied offering of products, cuts, value added and cooking ready cuts has appeared over the last two years.

The food service industry such as fast food chains, hotel chains and restaurants, form a strong buying group of which the fast food chains and large hotel chains form the most powerful buying segment.

Institutions such as hospitals, nursing homes, educational facilities and the military are a cost conscious market and in the purchase of their meat and meat products choose suppliers mainly on price. Their suppliers are meat processors and wholesalers.

As the number of supermarket/wholesale meat buyers decreases, any factors that might negatively influence the consistency and eating quality of lamb and other sheep meat table cuts will be a powerful trigger to reduce prices. This applies also for the service industry with its large chains who will not accept that their customers will be affected by poor meat quality.

Consumers
Consumers increasingly opt for convenient meat cuts that can be purchased on the way home from work and then quickly grilled, fried or roasted with a predictable pleasurable eating experience. Usually both adult partners in a family work. They also appear to be more health conscious than a generation ago.

Fresh lamb has to compete with fresh beef, chicken and fish and also convenience foods such as frozen dinners.

Additionally, younger consumers have less experience than their parents in handling meat. They heavily rely on supermarkets and butchers for information on cooking instructions and storage time for specific cuts of meat. Switching costs to other meats are low and a bad eating experience can easily turn a consumer off a particular cut or a particular type of meat.

Predictability and convenience in all aspects of meat usage from the buying experience, preparation, cooking to the eating experience are strong factors for consumers to choose specific types and cuts of meat.

Pet food industry

The pet food industry purchases a quantity of manufacturing meat and also co-products such as meat meal, tallow and edible offal. The quality requirements of the pet food industry are substantial.

Co-products industry

Skins and offal and rendered products are purchased from meat processors and processed to various value added stages for export and domestic use.