On farm

Benchmarking Lamb Eating Quality

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EXECUTIVE SUMMARY

RESEARCH SUMMARY

Consumers perceive lamb to be unreliable with regard to eating quality. The eating quality of lamb is influenced by a number of factors from conception to cooking including: breed, environment, on-farm practices, slaughter and post-slaughter treatments and cooking methods employed by consumers. Improving consistency in eating quality of lamb particularly tenderness, has the potential to increase both consumer satisfaction and consumption levels of lamb, in both domestic and export markets. Previous AMLC research (Ashton-Jones 1986; AMLC 1995) identified variability in tenderness of lamb. Channon et al. (1993) found in a study conducted amongst retailers, wholesalers and boning rooms in Melbourne from July 1991 to June 1993 that tenderness of lamb was inconsistent. Lamb eating quality was influenced by season, with lamb being less tender in late autumn and winter. Post-slaughter management practices such as carcass ageing was also shown to significantly affect lamb eating quality.

This project examined tenderness of lamb in capital cities in Australia where Branded Lamb Alliances have been functioning. To provide a valid comparison, the quality of lamb traded through normal marketing channels in the ‘generic’ industry was monitored in this study in four Australian capital cities. The Warner-Bratzler shear force test, sometimes in combination with trained panel or consumer sensory evaluations, was the standard test used in this study to define the toughness/tenderness of Australian lamb.

In this project, retail butchers and supermarkets in Melbourne, Sydney, Canberra and Perth handling 'generic' lamb were visited in December 1997, March 1998, June 1998 and October 1998. Retail outlets handling lamb marketed through two established Alliances were also visited in December 1997, March 1998, June 1998 and October 1998 on the same day as 'generic' outlets. Lamb midloins from different lamb carcasses were purchased from each store, then de-boned and de-fatted prior to freezing on the day of purchase. All denuded loins were then sent to the Victorian Institute of Animal Science, Werribee. Loins were thawed and muscle pH and tenderness, using a Warner-Braztler shear force blade fitted to an Instron Universal Testing Machine, was measured on each loin.

KEY FINDINGS

This research identified that no significant differences in average WB shear force values were found for lamb due to season of purchase, with average WB values ranging from 3.49 kg in December 1997 to 3.72 kg in June 1998.

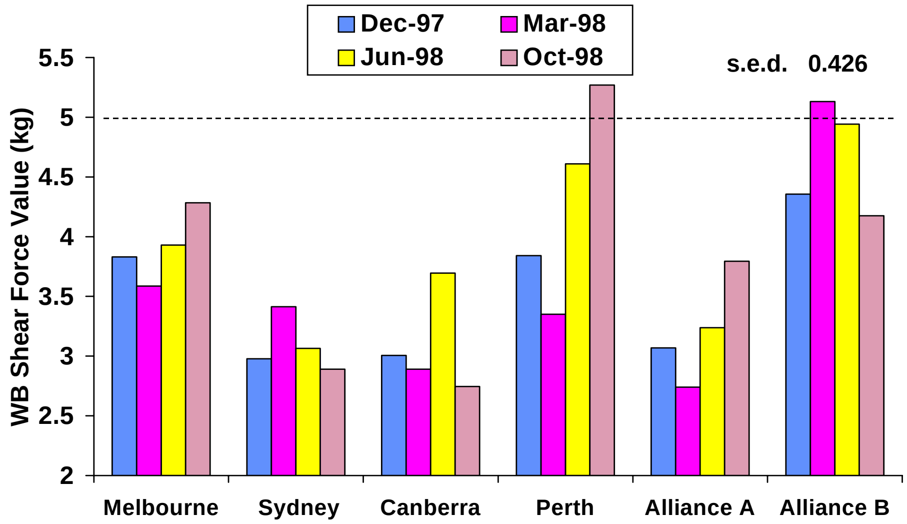
Significant differences in WB shear force values were, however, found between lamb midloins purchased at the retail level in the four different capital cities and in the two Alliances. Overall, lamb purchased from stores involved in Alliance B had a significantly higher average WB shear force value (4.65 kg) compared with lamb purchased in Alliance A (3.24 kg), Sydney (3.07 kg) and Canberra (3.07 kg). Lamb purchased in Melbourne (3.91 kg) and Perth (4.30 kg) was intermediate in terms of average WB values (Table A).

Table A: Effect of purchasing lamb from retail outlets in Melbourne, Sydney, Canberra and Perth or from retail outlets associated with Branded Lamb Alliance A and B on WB shear force values (kg) of lamb (M. longissimus lumborum).

	Average WB Shear Force Value (kg)	
Melbourne	*3.91*[b]	*(n=302)*
Sydney	*3.07*[a]	*(n=273)*
Canberra	*3.07*[a]	*(n=86)*
Perth	*4.30*[bc]	*(n=80)*
Alliance A	*3.24*[a]	*(n=88)*
Alliance B	*4.65*[c]	*(n=80)*
s.e.d.	*0.208*	
P	*<0.001*	

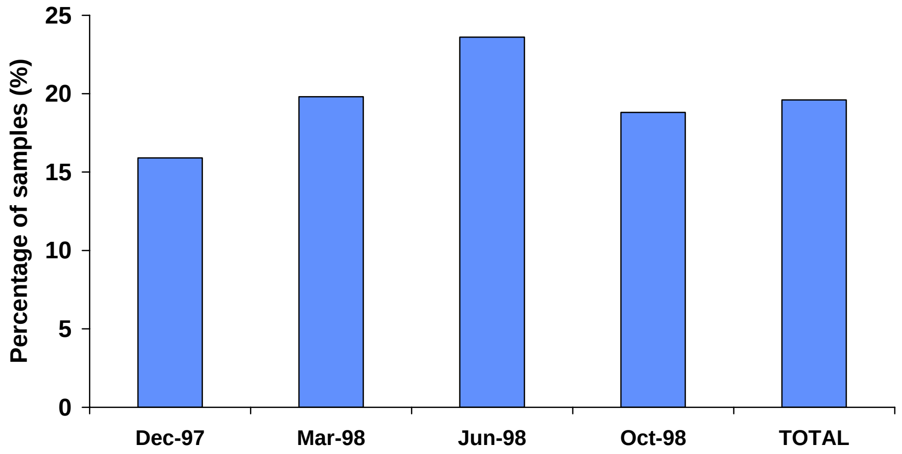
Figure A illustrates that place of purchase and season influenced average WB shear force values of lamb. Lamb purchased in Perth in October 1998 had significantly higher average WB values compared with lamb purchased in the other three capital cities as well as Alliances A and B. Importantly, lamb sourced through alliances may not meet consumer expectations of high eating quality

Figure A: Average WB shear force values of lamb midloins purchased in retail outlets in four capital cities and in Alliances A and B from December 1997 to October 1998.



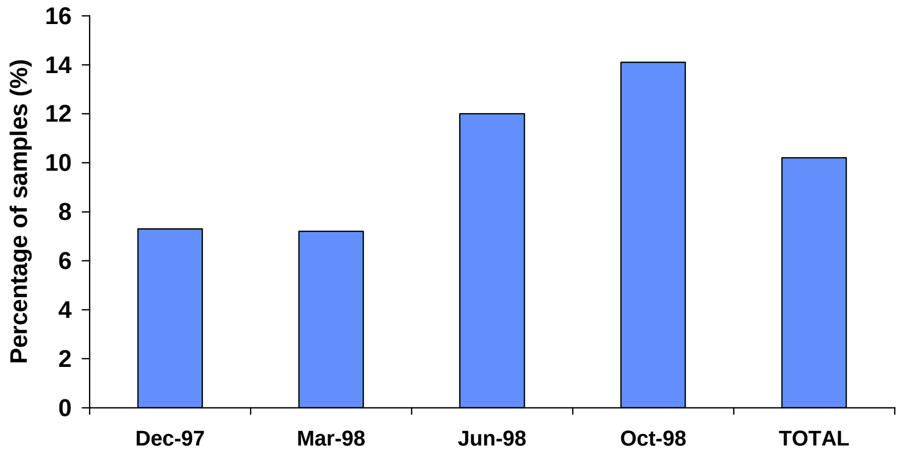
As studies have not yet been conducted to determine the sensitivity of Australian consumers to different levels of tenderness as measured using the WB shear force test it is not yet clear at what level Australian consumers consider lamb to be of unacceptable eating quality. Data has therefore been presented for two WB shear force cut-off values- 5 kg and 6 kg. Overall, the proportion of lamb midloins purchased in this study that recorded WB shear force values greater than 5 kg was 20% (Figure B), whilst 10% of lamb purchased in this study recorded WB values greater than 6 kg (Figure C). The proportion of lamb purchased in this study recording WB shear force values greater than 5 kg ranged from 16% in December 1997 to *24% in June 1998.*

Figure B: Proportion of lamb midloins purchased in December 1997 and March, June and October 1998 recording WB shear force values greater than 5 kg



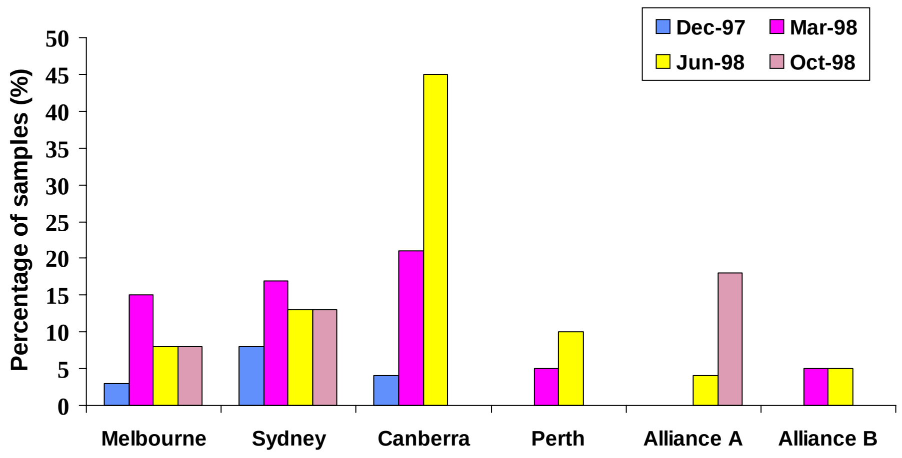
A higher proportion of lamb purchased in October 1998 recorded WB values greater than 6 kg (14%) compared with lamb purchased at all other times.

Figure C: Proportion of lamb midloins purchased in December 1997 and March, June and October 1998 recording WB shear force values greater than 6 kg



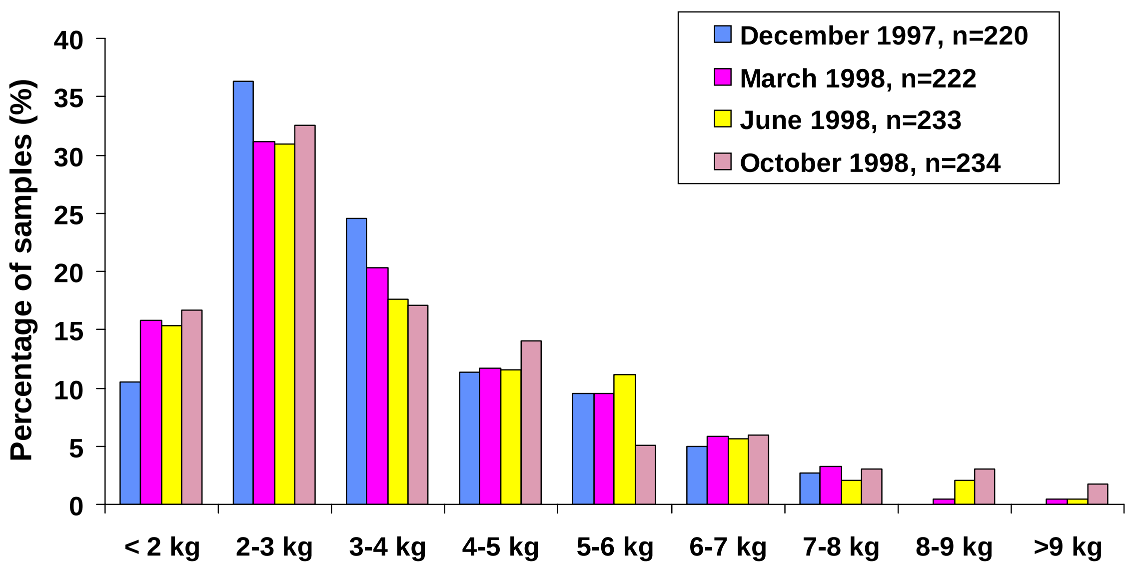
Generally, muscle pH was not found to explain high WB shear force values obtained for lamb assessed in this study. Only 5% of lamb purchased from Alliance B stores in March and June 1998 recorded muscle pH greater than 5.8, whilst in December 1997 and October 1998 no lamb sourced from this Alliance had a high muscle pH (Figure D). In June 1998, 45% of lamb midloins purchased in Canberra had an ultimate pH greater than 5.8.

Figure D: Proportion of lamb midloins purchased in Melbourne, Sydney, Canberra, Perth, Alliance A and Alliance B recording muscle pH > 5.8 in December 1997 and March, June and October 1998



The findings from this study indicate that lamb available to consumers is variable in eating quality, at least when measured objectively, as illustrated in Figure E..

Figure E: Proportion of lamb midloins purchased recording WB shear force values within the ranges of: < 2kg, 2-3 kg, 3-4 kg, 4-5 kg, 5-6 kg,6-7 kg, 7-8 kg, 8-9 kg and > 9 kg in December 1997 and March, June and October 1998



The results of this study are very encouraging for the Australian lamb industry as the majority of lamb achieved an acceptable level of tenderness (based on WB shear force values). However, in this increasingly discerning marketing environment, the industry can not afford to be complacent and it is recommended that pro-active steps be taken to overcome the unacceptable variability in tenderness as identified in this study.

OBJECTIVES

The objectives of this project were to assess the variability in tenderness and muscle pH of lamb available at the retail level in four Australian capital cities and compare this with lamb purchased in stores handling lamb from two different Alliances.

The specific objectives of the project were:

Establish a protocol for objectively assessing tenderness of lamb at the retail level by December 1997.

Implement a system of randomly testing lamb product from 'generic' and 'alliance' systems as a basis for establishing national benchmarks for lamb eating quality by December 1997.

Provide a confidential report describing the findings of the study by December 1998.

To provide samples of known Warner-Braztler Shear Force to R&G Formulations for NIR testing.

METHODOLOGY

A. *Generic Product*

Sampling of lamb midloins was conducted in retail butchers and supermarkets located in Melbourne, Sydney, Canberra and Perth in December 1997 and March, June and October 1998. Lamb midloins (M. longissimus lumborum (LL)) were randomly purchased from selected large retail butchers (2 midloins per store) and supermarkets (3 samples per store) in Melbourne and Sydney. In Canberra, two samples were randomly purchased from five large retail butchers and five supermarkets, whilst in Perth, two samples were randomly purchased from three large retail butchers and seven supermarkets.

B. *Alliance Product*

Tenderness of lamb midloins from branded lamb alliances was also assessed in this study. In Alliance A, two samples were randomly purchased from five selected large retail butchers and five supermarkets whilst in Alliance B, two samples were randomly purchased from three large retail butchers and seven supermarkets.

All midloins were deboned and denuded prior to freezing at -20ºC on the eve of each sampling day. Muscles were transported frozen to VIAS, Werribee for tenderness assessment using the Warner Bratzler (WB) shear force blade fitted to an Instron Universal Testing Machine Model 4465. Lamb was prepared, cooked and assessed for tenderness using methods outlined by Bouton et al. (1971). Muscle pH was measured in product after thawing, prior to cooking.

MAJOR RESEARCH FINDINGS

Four benchmarking audits were conducted in this project and key findings from each audit were as follows:

December 1997:

Average WB shear force values were higher for lamb purchased in Melbourne, Perth and Alliance B compared with Sydney, Canberra and Alliance A (Figure A). The proportion of lamb midloins recording WB shear force values greater than 5 kg was 16% (Figure B) whilst 7% of lamb recorded WB shear force values greater than 6 kg (Figure C). No significant differences were found in WB shear force values of lamb purchased at supermarkets or retail butchers. Lamb purchased in Melbourne was found to have a lower average muscle pH compared with lamb purchased in Sydney and Canberra. Overall, average muscle pH of lamb purchased in Melbourne, Sydney, Canberra, Perth, Alliance A and Alliance B were within the normal range for lamb of 5.4 to 5.8. It was also found that only 3%, 4% and 8% of lamb purchased in Melbourne, Canberra and Sydney, respectively, recorded muscle pH greater than 5.8 (Figure D).

March 1998

Lamb purchased in all capital cities and in Alliance A and B was variable in tenderness. Overall, lamb purchased in Alliance B had a significantly higher average WB shear force value compared with lamb purchased in Melbourne, Sydney, Canberra, Perth and Alliance A (Figure A). Differences in muscle pH were not considered to account for the variability in tenderness of lamb purchased in Alliance B (Figure D). Overall, lamb purchased in Canberra, Perth and Alliance A was less variable in tenderness compared with lamb purchased in Melbourne, Sydney and Alliance B. No significant differences in WB shear force values and muscle pH of lamb purchased at either supermarkets or retail butchers were found in this audit.

June 1998

Lamb purchased in Alliance B once again had a significantly higher average WB shear force value compared with lamb purchased in Melbourne, Sydney, Canberra and Alliance A. Inconsistency in tenderness of lamb was also identified in all capital cities and both Alliances involved in this study.

October 1998

Lamb purchased in Perth in October 1998 recorded significantly higher average WB shear force values compared with lamb purchased in Alliances A and B, Melbourne, Sydney and Canberra. As this study was not aimed to determine those factor(s) that may have contributed to inconsistencies in tenderness, this problem was not considered to be pH-related as no lamb midloins purchased in Perth had a muscle pH exceeding 5.8.

Inconsistency in tenderness of lamb was again identified in all capital cities and Alliances involved in this study.

CONCLUSIONS

From the four audits conducted as part of this benchmarking study, it was identified that:

(a) Inconsistency in tenderness was identified in lamb purchased in all four capital cities.

(b) Lamb available to consumers is variable in eating quality, at least when measured objectively and may differ between place of purchase.

(c) Importantly, these results indicate that lamb sourced through alliances may not necessarily meet consumer expectations of high eating quality.

Those factor(s) contributing to variability in tenderness of lamb identified in this study are not traceable because no background information was obtained for lamb purchased in this study.

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SECTION 1:

1. BACKGROUND

The Australian lamb industry must compete in a highly competitive food market where its future success is dependent on understanding and satisfying the needs of its customers and consumers. Factors including food safety, meal convenience, price, dietary concerns and consistency of eating quality all collectively influence customer satisfaction with lamb. Tenderness, juiciness and flavour have been identified as the key eating quality attributes of lamb important to consumers but there is no simple, low cost objective tool industry can reliably use to measure and grade carcasses for eating quality traits. The Warner-Bratzler shear force test, sometimes in combination with trained panel or consumer sensory evaluations, has been the standard test used to define the toughness/tenderness of Australian lamb.

The eating quality of lamb is influenced by a number of factors from conception to cooking including: breed, environment, on-farm practices, slaughter and post-slaughter treatments and cooking methods employed by consumers. In September 1997, a Background Paper on Eating Quality of Lamb was released by Meat Research Corporation to provide general background of issues related to eating quality of lamb. This Paper identified a number of key issues that must be addressed to allow the Australian lamb industry to meet consumer demands for lamb including:

(a) Consumer research indicated that tenderness is the key attribute consumers use to compare lamb with its competitors, namely beef, pork and chicken.

(b) Fat and cholesterol is the most negative attribute of lamb and may influence the overall assessment of eating quality by consumers.

There are no routinely measured benchmarks of consumer satisfaction of lamb in terms of tenderness and fat content.

No consumer data presently exists on perceived variability and seasonality of lamb eating quality.

There is also no information on whether eating quality attributes of lamb produced by specialist lamb producers and marketed through branded lamb alliances is improved when compared with lamb marketed through traditional channels. This project was therefore developed to identify benchmarks for lamb tenderness at the retail level.

Outcomes from this project will be used to determine whether the lamb industry should move toward an Eating Quality Standards program to improve consistency in eating quality by implementing practices from conception to consumption which guarantee high eating quality. There is currently pressure on the lamb industry to move this way due to the development of the EQS program for Australian beef as it may be perceived by consumers that as lamb lacks such a program it may be an inferior product compared with beef.

2. INTRODUCTORY TECHNICAL INFORMATION

2.1 Eating Quality Assurance for Lamb

The Meat Standards Australia program for beef was initially developed to overcome the problem that physical attributes are not useful in the prediction of eating quality. In the Eating Quality Standards Program for beef, research has examined the effects of breed; plane of nutrition; rate of pH decline post-slaughter; tenderstretching; carcass grade; marbling score and post-slaughter ageing of carcasses/primals on eating quality. Despite considerable research conducted in these areas in lamb, no system has yet been implemented to link such factors mentioned above to eating quality attributes of lamb, particularly tenderness.

AUS-MEAT classifications do not relate to the eating quality of lamb and many people consider that a description/grading system, which provides the consumer with information about eating quality, would be helpful in meeting market requirements for high quality lamb. Modern consumers require products, which are quality assured. Although quality assurance will initially guarantee human hygiene and food safety requirements, consumers will increasingly require practices that improve the consistency of eating quality of lamb. The lack of a consistent product is a problem facing the Australian prime lamb industry. Inconsistency in product quality results in consumers being unable to reliably purchase lamb of consistently high quality. This lack of consistency is related not only to eating quality, but also to seasonal supply, variability in carcass weight and fatness of lambs slaughtered and lack of differentiation of lamb differing in age (ie. sucker lambs of around 4-5 months of age compared with older lambs). The categorisation of 'lamb' includes all animals with no permanent incisors. In effect, this means sucker lambs of five months of age with no growth checks and carryover lambs of twelve months of age which have experienced nutritional setbacks can both be marketed and traded as lamb. This issue alone may be contributing to inconsistency in eating quality of lamb.

2.1.1 Tenderness

Consumers use the lamb quality characteristics of tenderness, juiciness and flavour to describe the eating quality attributes of fresh lamb. Of these, tenderness is considered the most important quality characteristic of lamb. Tenderness is dependent upon a number of biological factors including age, nutritional management and sex of the animal, pre-slaughter handling and post-slaughter management factors, including chilling temperature, electrical stimulation and length of carcass ageing.

Repeat purchasing of lamb by consumers is determined by the palatability traits (tenderness, juiciness, flavour and aroma). Tenderness is generally considered as a two component system with a myofibrillar component and a connective tissue component (Harris and Shorthose 1988). The myofibrillar component is responsible for muscle contraction and the role of connective tissue is to anchor muscle tissue and provides cohesion between muscle fibres. Tenderness differences can therefore be attributed to the contractile state of the muscle fibres (sarcomere length) and/or the amount, type and nature of the connective tissue (Marsh 1977). The variability in tenderness of the myofibrillar component has been attributed to differences in pre- and post-slaughter management factors, since sarcomere structure does not markedly differ within a species (Shorthose and Harris 1991).

The myofibrillar component of tenderness is influenced by muscle temperature at rigor, skeletal restraint, extent of muscle contraction post-slaughter, ultimate pH, length of ageing post-slaughter and degree of cooking. The relationship between ultimate pH and tenderness in lamb muscles free to shorten is dependent upon the rate of decline of both muscle pH and temperature post-slaughter (Harris and Shorthose 1988). In lamb, as ultimate pH increases from 5.5 to 6.0, decreases in lamb tenderness do not always occur (Bouton et al. 1973). Newbold and Harris (1972) stated that tenderness is greatly influenced by both conditions prevailing during the period between slaughter and the full development of rigor mortis and post-motem shortening.

Cold shortening is the reduction in sarcomere length due to exposure to cold temperatures while muscle pH is still high (>6.0). The relationship between cold shortening and tenderness is complex. A decrease in sarcomere length of 20% from initial length does not appear to affect tenderness but toughness increases rapidly with further shortening reaching a peak with shortening of approximately 40%. Muscles having a sacromere length of 2.0 to 2.5 μm have been reported to be tender, those having a sarcomere length of 1.7 to 2.0 μm moderately tender and those having a sarcomere length of 1.5 to 1.7 μm being extremely tough. The extent of cold shortening is dependent upon a number of factors. Muscles from older lambs may have a greater capacity to cold shorten compared with those from younger animals. Cold shortening can be reduced by careful control of chilling. Optimal conditions for normal LL muscle is to chill to temperatures below 20°C within two hours post-slaughter and chilling not below 10°C at six hours to avoid cold shortening.

Electrical stimulation prevents cold shortening by causing a more rapid rate of post-slaughter metabolism in muscle. This results in a lower pH while muscle temperatures are still high which maximises proteolysis (Dutson and Pearson 1985).

Meat will become more tender during extended storage post-rigor (Dransfield et al. 1980-81), a process also referred to as ageing. Some of the desirable eating quality characteristics, particularly tenderness, increase with post-slaughter storage at 0-5°C. In lamb, improvements in tenderness due to ageing are rapid in the first 1-2 days post-slaughter and then continue at a slower pace and plateau at around 4-5 days post-slaughter. Shorthose et al. (1986) recommended that lamb carcasses aged for at least 3 days post-slaughter may yield more tender meat.

2.1.2 Ultimate pH

Irreversible anaerobic glycolysis occurs in muscle after death due to the removal of oxygen (Lawrie 1985). The amount of lactate produced in a muscle after death and the extent of the decrease in postmortem muscle pH is dependent upon the concentration of glycogen present in the muscle at slaughter (Howard 1963). Glycogen, the major storage carbohydrate present in animal cells, comprises about 1% of the wet weight of resting muscle (Lawrie 1979). In sheep muscle, glycogen concentrations of less than 0.65% at slaughter can limit lactate production sufficiently to increase the ultimate pH of muscle.

The pH of living muscle is about 7.0 and in well-fed, rested animals declines to an ultimate pH of about 5.4 to 5.8 at 24 hours post-slaughter. Ultimate pH is the final pH attained in muscle resulting from either a lack of muscle glycogen or inactivation of glycolytic enzymes. Ultimate pH of lamb muscle can influence colour, water holding capacity, cooking loss as well as keeping quality of meat. However, neither breed (Devine and Chrystall 1989) nor age (Pinkas et al. 1982) appear to influence ultimate pH. Bray et al. (1994) concluded that although genetic effects on meat quality are small, if animals are under exhausting and stressful conditions prior to slaughter, effects of breed on stress may be enhanced.

Pre-slaughter handling can influence the rate and extent of post-mortem glycolysis of ovine muscle due to increased muscular activity (Chrystall et al. 1982). This may result in an increase in muscle temperature and also a change in concentrations of muscle metabolites at death (Shorthose 1978). Stress immediately prior to slaughter due to transport, mustering or nutrition has important consequences for meat quality, particularly if lambs do not have time to restore muscle glycogen levels before slaughter (Shorthose 1980). Yarding, selection and loading of sheep onto trucks prior to slaughter has also been shown to influence ultimate pH (Shorthose 1978). The slow release of adrenaline that accompanies stress is claimed to be a major cause of glycogen exhaustion and high pH meat (Howard and Lawrie 1956). Wythes and Shorthose (1984) stated that if the pH value of the loin (M. longissimus thoracis et lumborum) muscle is 5.8 or less 24 hours post-slaughter, it is unusual for any other muscles in the carcass to have an ultimate pH above 6.0.

Water holding capacity increases linearly with increasing ultimate pH. The water holding capacity of meat is defined as the ability of the muscle proteins to bind water, with the amount of water immobilised determine by the structural configuration of myofibrillar proteins and by ionic interactions between the sarcoplasmic and myofibrillar proteins. Water holding capacity can be related to juiciness, which in turn is directly related to the intramuscular lipid and moisture content of meat (Cross et al. 1976). Juiciness is probably the most important attribute of meat quality after tenderness. Initial juiciness of meat is influenced by method of cookery whilst sustained juiciness is affected by the intramuscular fat content which may directly or indirectly stimulate salivation (Dikeman 1987). Szczesniak (1968) suggested that juiciness may have a large influence on organoleptic tenderness.

Cooking can induce a large reduction of water holding capacity due to the degradation of myofibrillar structure and collagen. The degree of doneness of cooked lamb can influence consumer scores for both tenderness and juiciness. It has been shown that as internal temperature of lamb increases, tenderness of lamb measured objectively decreases. Research in Australia has concentrated on investigating factors influencing tenderness of lamb primarily by objectively measuring tenderness, using the Warner-Bratzler (WB) shear force blade fitted to an Instron Universal Testing Machine or by also using a trained taste panel, generally with panellists calibrated to WB scores.

Considerable research has identified that post-slaughter management of lamb carcasses can significantly influence lamb eating quality over and above on-farm effects. Therefore, the ability of the prime lamb industry to improve the consistency in lamb eating quality will require all sectors of the marketing chain, from producers to retailers, to work together to ensure that best practice systems are adopted.

SECTION 2:

3. RESEARCH METHODOLOGY, RESULTS AND DISCUSSION

3.1 Background

Tenderness is the most important characteristic of eating quality of meat. AMLC market research identified that consumers consider that lamb is not reliably tender, however there is little objective data on tenderness of lamb at the retail level. Overall monitoring of eating quality will assist the industry to improve overall quality and minimise variability in eating quality of lamb. Palatability Assurance Critical Control Points (PACCP) have been identified in several research programs to be important for lamb eating quality. The establishment of Branded Lamb Alliances (BLA) may potentially provide means of determining effects of different on-farm, pre-slaughter and post-slaughter management systems on eating quality attributes of lamb.

This project examined tenderness of lamb in capital cities in Australia where Branded Lamb Alliances have been functioning. The main focus for sampling will be on ‘generic’ lamb products in stores without management aimed at improving tenderness. To provide a valid comparison, the quality of lamb traded through normal marketing channels in the generic industry was monitored in this study in four Australian capital cities.

The need for this study arose from AMLC research that lamb does not always meet consumer expectations for tenderness. No studies have been conducted which provide benchmark information about the quality of lamb purchased by consumers across Australia.

3.2 Objectives

This project aimed to identify variability in lamb tenderness at the retail level on a quarterly basis from December 1997 to October 1998 and potentially identify key areas to reduce variability in tenderness.

The specific objectives of this project were to:

(a) Determine whether meat quality standards or systems such as Palatability Assurance Critical Control Points (PACCP) need to be introduced by the lamb industry to improve consistency of lamb eating quality.

(b) Establish a protocol for objectively assessing tenderness of lamb at the retail level by December 1997.

(c) Implement a system of randomly testing lamb product from 'generic' and 'alliance' systems as a basis for establishing national benchmarks for lamb eating quality by December 1997.

By December 1996, to determine whether alliances with control of product from production to retail are providing products of more consistent eating quality than lamb obtained from generic outlets, and where feasible to define reasons for any differences

Provide a confidential report describing the findings of the study by December 1998.
To provide samples of known Warner-Bratzler Shear Force to R&G Formulations for NIR testing.

3.3 Methodology

3.3.1 Generic Product

Sampling of lamb midloins was conducted in retail butchers and supermarkets located in Melbourne, Sydney, Canberra and Perth in December 1997 and March, June and October 1998. Lamb midloins (M. longissimus lumborum) were randomly purchased from selected large retail butchers (2 midloins per store) and supermarkets (3 samples per store) in Melbourne and Sydney. In Canberra, two samples were randomly purchased from five large retail butchers and five supermarkets, whilst in Perth, two samples were randomly purchased from three large retail butchers and seven supermarkets.

3.3.2 Alliance Product

Tenderness of lamb midloins from branded lamb alliances was also assessed in this study. In Alliance A, two lamb midloins were randomly purchased from five selected large retail butchers and five supermarkets whilst in Alliance B, two lamb midloins were randomly purchased from three large retail butchers and seven supermarkets.

To ensure that lamb midloins purchased in this study were from different lambs, only one midloin per lamb carcass was purchased in any one retail outlet. All midloins were deboned and denuded prior to freezing at -20ºC on the eve of each sampling day. Muscles were transported frozen to VIAS, Werribee for tenderness assessment. Lamb was thawed overnight at 2°C prior to conducting tests for objective tenderness and muscle pH. All muscles were prepared into 80 ± 2 g samples, wrapped separately in thin plastic bags and cooked in a waterbath at 80°C for 1 hour (Bouton et al. 1971). Samples were then cooled in cold running water for 30 minutes, dried in paper towel to remove excess moisture and weighed to determine cooking loss. Tenderness of samples with a cross-sectional area of 1cm2 was measured using the Warner Bratzler (WB) shear force blade fitted to an Instron Universal Testing Machine Model 4465.

Muscle pH was measured in product after thawing, prior to cooking. Muscle pH was determined using a Jenco pH meter Model 6007 with a direct pH probe which was inserted into muscle samples.

Retail butchers and supermarkets visited in Melbourne, Sydney, Canberra and Perth were initially selected on a random basis and whenever possible were included in each benchmarking audit. No data except price per kilogram and total purchase price of lamb midloins was obtained in the first three studies conducted.

The total number of stores visited and total number of lamb midloins purchased in each capital city and from Alliances A and B are shown in Table 1.

3.3.3 Statistical analyses

Data in this study was analysed by Analysis of Variance using Genstat 5.3.2 program (Payne et al. 1986) to determine significant differences in tenderness, muscle pH and cooking loss between all LL muscles due to season, place of purchase and type of retail outlet.

Table 1: Total number of stores visited and lamb midloins purchased from generic retail outlets in Melbourne, Sydney, Canberra and Perth and retail outlets in Alliance A and Alliance B from December 1997 to October 1998.

		No. of stores visited	**No. of lamb midloins purchased**
December 1997	Melbourne	30	76
	Sydney	26	50
	Canberra	10	19
	Perth	10	20
	Alliance A	9	22
	Alliance B	10	20
	TOTAL	**95**	**220**
March 1998	Melbourne	30	75
	Sydney	27	65
	Canberra	12	23
	Perth	10	20

		No. of stores visited	No. of lamb midloins purchased
	Alliance A	8	17
	Alliance B	10	20
	TOTAL	**97**	**222**
June 1998	Melbourne	30	78
	Sydney	28	68
	Canberra	10	20
	Perth	10	20
	Alliance A	11	27
	Alliance B	10	20
	TOTAL	**99**	**233**
October 1998	Melbourne	29	73
	Sydney	31	77
	Canberra	10	21
	Perth	10	20
	Alliance A	9	18
	Alliance B	10	20
	TOTAL	**99**	**234**
	GRAND TOTAL	**390**	**909**

3.4 Results and Discussion

3.4.1 Tenderness

Effect of season on lamb tenderness

No significant differences due to season were found in tenderness of lamb, measured objectively using a WB shear force blade (Table 2).

Table 2: Effect of purchasing lamb in December 1997 and March, June and October 1998 on WB shear force value (kg) of lamb midloins (M. longissimus lumborum)

	Average WB shear force value (kg)
December 1997	3.49
March 1998	3.51
June 1998	3.72
October 1998	3.71
s.e.d.	0.150
P	n.s.

The box and whisker display in Figure 1 indicates that in June 1998, lamb purchased was more variable in tenderness compared with lamb purchased in December 1997. It is of interest to note that although the variability in tenderness of lamb purchased in March and October 1998 audits were similar, more outliers were identified in October 1998 compared with March 1998.

The box and whisker display presented in Figure 1 reflects the variation in WB shear force values of all lamb midloins purchased in December 1997 and March, June and October 1998. The vertical lines in Figure 1 illustrate the variation in tenderness due to season. The boxed area represents 50% of samples with the median represented by the horizontal line within the boxed area. The sample numbers above the box and whisker displays refer to outliers (ie. lamb midloins recording WB shear force values greater than 1.5 times the length of the boxed area).

Average WB shear force values for lamb (as presented in Table 2) were less than the 5 kg benchmark level below which Shorthose et al. (1986) proposed that lamb would be considered acceptable to Australian consumers. Despite this, Figure 1 illustrates considerable variability in tenderness of lamb purchased in each audit.

It was also assumed that the integrity of lamb sampled in this survey was accurate and the variation in eating quality of lamb observed was not due to product substitution.

Effect of place of purchase on lamb tenderness

Across sampling periods, lamb purchased in Sydney, Canberra and Alliance A was found to be significantly more tender compared with lamb purchased in Melbourne, Perth and Alliance B (Table 2).

Table 3: Effect of purchasing lamb from retail outlets in Melbourne, Sydney, Canberra and Perth or from retail outlets associated with Branded Lamb Alliance A and B on WB shear force values (kg) of lamb (M. longissimus lumborum).

	Average WB Shear Force Value (kg)	
Melbourne	3.91^{b}	(n=302)
Sydney	3.07^{a}	(n=273)
Canberra	3.07^{a}	(n=86)
Perth	4.30^{bc}	(n=80)
Alliance A	3.24^{a}	(n=88)
Alliance B	4.65^{c}	(n=80)
s.e.d.	0.208	
P	<0.001	

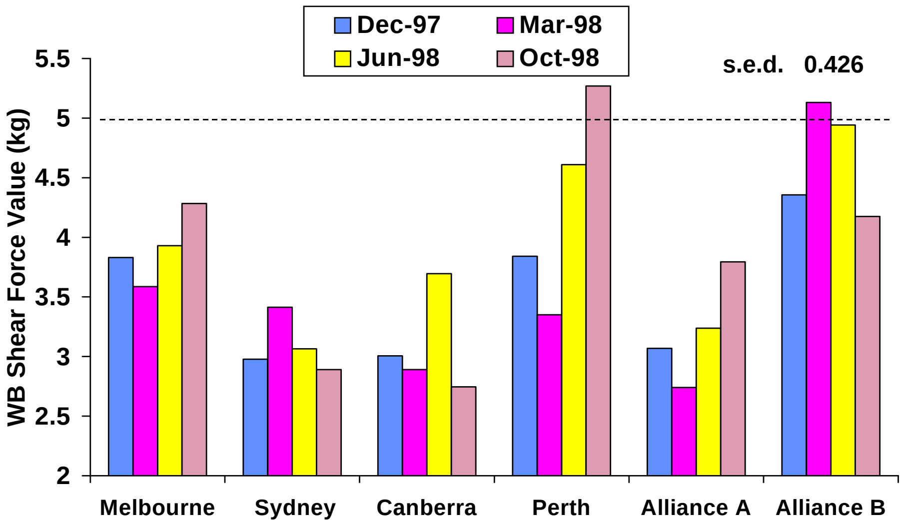
Variability in tenderness of lamb was also found within each capital city or Branded Lamb Alliance sampled in this study (Figure 2). It was found that lamb purchased in Alliance A and Canberra was less variable and more consistent in tenderness compared with lamb obtained in Melbourne, Perth and Alliance B. In Sydney, although variability in tenderness was similar to that of Canberra and Alliance A, more outliers were identified. However, factors contributing to this variability are unknown as this study was primarily designed to determine whether variability in tenderness existed, rather than to ascertain factor(s) contributing to this problem.

Figure 3 shows that the variability in tenderness of lamb purchased in generic and alliance retail outlets was similar. Although average WB shear force values were slightly higher for lamb from alliance outlets compared with generic outlets, this difference was not significant. Fewer midloins purchased from alliance outlets were identified as outliers compared to those from generic outlets. As indicated by the narrower width of the boxed area, there were significantly fewer alliance samples involved in this study compared with generic lamb samples.

Effect of season and place of purchase on lamb tenderness

Average WB shear force values of lamb midloins purchased in retail outlets in Melbourne, Sydney, Canberra, Perth, Alliance A and Alliance B in December 1997 and March, June and October 1998 are shown in Figure 4. Significant differences in WB values were found due to season and place of purchase with lamb purchased in Perth in October 1998 found to be significantly tougher ($P<0.001$) compared with lamb from all the other three capital cities and Alliances A and B. In March 1998, however, lamb from Alliance B was significantly tougher ($P<0.001$) compared with lamb purchased in Melbourne, Sydney, Canberra, Perth and Alliance A. In June 1998, lamb from both Perth and Alliance B was tougher ($P<0.001$) compared with Alliance A and the other three capital cities.

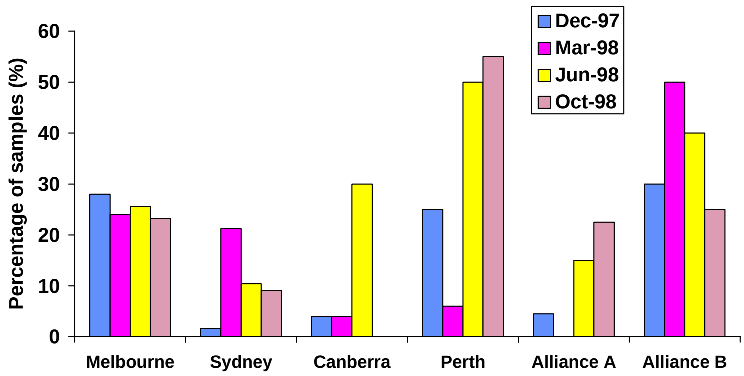
Figure 4: Average WB shear force values of lamb midloins purchased in retail outlets in four capital cities and in Alliances A and B from December 1997 to October 1998.



The proportion of samples purchased in Melbourne, Sydney, Canberra, Perth, Alliance A and Alliance B recording WB shear force values ranging from less than 2 kg to greater than 7 kg are presented in Appendix 1.

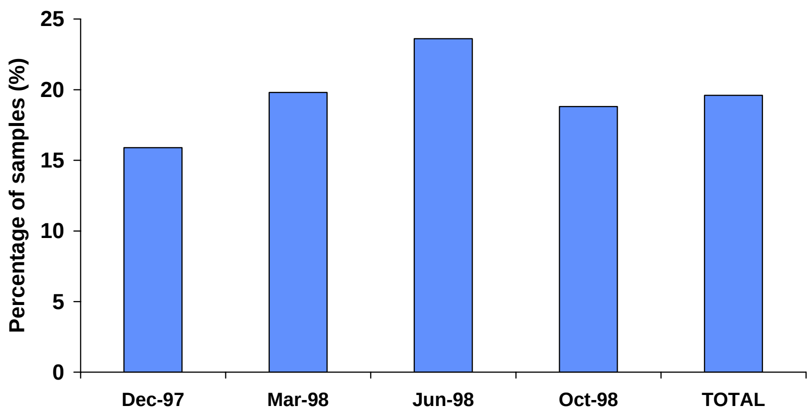
Figure 5 shows that the proportion of lamb midloins purchased in Melbourne at the retail level recording WB shear force values greater than 5 kg was consistent throughout this study ranging from 23% in October 1998 to 28% in December 1997. In Sydney, 21% of lamb midloins purchased in March 1998 recorded high WB shear force values, however, in June and October 1998 lamb tenderness was more consistent in quality with only 9-10% of midloins having high WB shear force values. In Canberra, 30% of lamb midloins in June 1998 recorded WB shear force values greater than 5 kg, which may have been related to a 'dark cutting' problem as 45% of lamb midloins purchased in this audit had muscle pH values exceeding 5.8. In Perth, 50% and 55% of midloins purchased in June and October 1988, respectively, recorded WB shear force values exceeding 5 kg. It is clear from Figure 5 that the incidence of tough lamb from Perth tended to increase from December 1997 to October 1998. In Alliance B, however, consistency in lamb tenderness tended to improve throughout the duration of this study with incidence levels of tough lamb declining from 50% in March 1998 to 23% in October 1998.

Figure 5: Proportion of lamb midloins purchased in Melbourne, Sydney, Canberra, Perth, Alliance A and Alliance B recording WB shear force values greater than 5 kg in December 1997 and March, June and October 1998



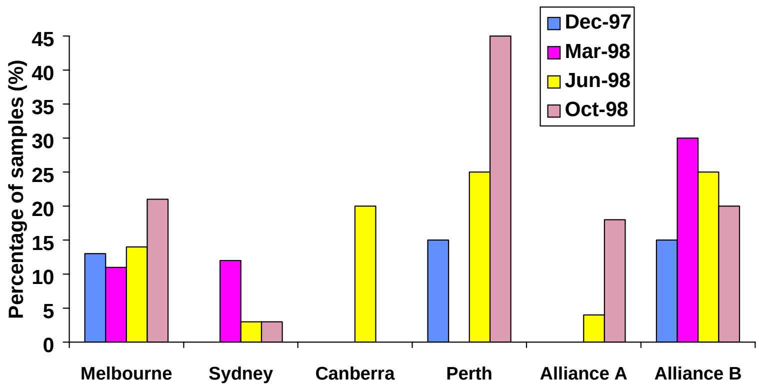
The proportion of lamb purchased in this study recording WB shear force values greater than 5 kg ranged from 16% in December 1997 to 24% in June 1998 (Figure 6). Across the four audits conducted in this study, 20% of lamb midloins recorded WB values greater than 5 kg.

Figure 6: Proportion of lamb midloins purchased in December 1997 and March, June and October 1998 recording WB shear force values greater than 5 kg



As sensory evaluations of lamb were not conducted as part of this study, it is not known whether lamb recording a WB shear force value of greater than 5 kg would be unacceptable to consumers. Data presented in Figures 7 and 8 therefore reflect the proportion of lamb midloins purchased that had WB shear force values exceeding 6 kg. From Figure 7, it is noteworthy that, even at a cut-off level of 6 kg, consumers may consider 45% of lamb purchased in Perth in October 1998 unacceptable in tenderness. It was also found that 15% to 30% of lamb sourced from Alliance B retail outlets may be considered unacceptable due to high WB shear force values obtained.

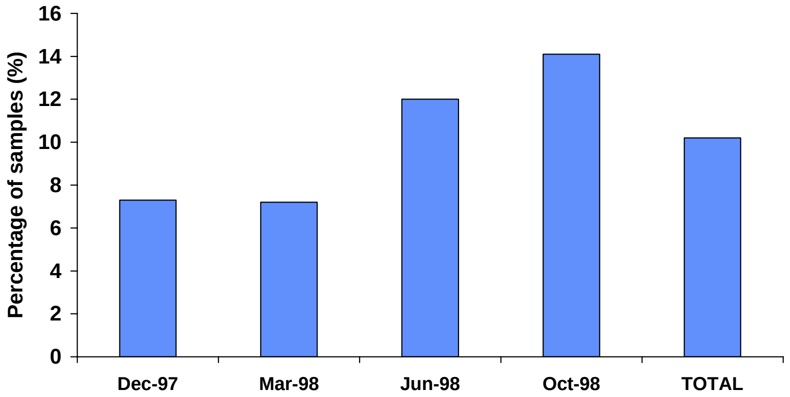
Figure 7: Proportion of lamb midloins purchased in Melbourne, Sydney, Canberra, Perth, Alliance A and Alliance B recording WB shear force values greater than 6 kg in December 1997 and March, June and October 1998



As shown when the WB shear force value of 5 kg was used as a cut-off for acceptability, the proportion of lamb sourced in Melbourne recording WB shear force values greater than 6 kg remained consistent from December 1997 to October 1998. It may be suggested that although lamb available in October 1998 would mainly be ‘new season lamb’, considerable variation and inconsistency in tenderness was observed in several cities in this study at this time. For example, in Melbourne it was found that 21% of lamb had WB shear force levels of greater than 6 kg, whilst 45%, 18% and 20% of lamb midloins purchased in Perth, Alliance A and Alliance B, respectively, may also be considered tough. As previously stated, possible reasons to explain these findings cannot be provided as this benchmarking study was only designed to measure variability in tenderness.

The proportion of lamb purchased in this study recording WB shear force values greater than 6 kg ranged from 7% in December 1997 and March 1998 to 14% in October 1998 (Figure 8). Across the four audits conducted in this study, 10% of lamb midloins recorded WB values greater than 6 kg.

Figure 8: Proportion of lamb midloins purchased in December 1997 and March, June and October 1998 recording WB shear force values greater than 6 kg



Effect of type of retail outlet on lamb tenderness

It was identified in this study that lamb purchased from retail butchers recorded lower WB shear force values compared with supermarkets (Table 4).

Table 4: Effect of purchasing lamb from retail butchers or supermarkets on WB shear force values (kg) of lamb midloins (M. longissimus lumborum).

	Average WB Shear Force Value (kg)	
Retail Butcher	3.26[a]	(n=389)
Supermarket	3.87[b]	(n=520)
s.e.d.	0.114	
P	<0.001	

Across all capital cities, the variability in tenderness of lamb purchased in supermarkets was also found to be greater compared with retail butchers (Figure 9).

Significant differences in tenderness of lamb were also found between retail butchers and supermarkets in Melbourne, Sydney, Canberra, Perth, Alliance A and Alliance B visited in December 1997 and March, June and October 1998 (Table 5). However, these differences between retail butchers and supermarkets in each place of purchase sampled at different times are inconsistent.

Table 5: Effect of season, place of purchase and type of retail outlet on average WB shear force values (kg) of lamb midloins (M. longissimus lumborum)

Month	City	Average WB Shear Force Values (kg)			
		Retail Butcher		Supermarket	
December 1997	Melbourne	3.48	(n=31)	4.07	(n=45)
	Sydney	3.32	(n=30)	2.66	(n=33)

Month	City	Average WB Shear Force Values (kg)			
		Retail Butcher		Supermarket	
	Canberra	3.20	(n=9)	2.83	(n=10)
	Perth	2.97	(n=6)	4.22	(n=14)
	Alliance A	2.83	(n=10)	3.26	(n=12)
	Alliance B	4.15	(n=6)	4.44	(n=14)
March 1998	Melbourne	2.92	(n=30)	4.03	(n=45)
	Sydney	3.20	(n=28)	3.57	(n=37)
	Canberra	2.71	(n=11)	3.03	(n=14)
	Perth	3.87	(n=6)	3.13	(n=14)
	Alliance A	2.89	(n=8)	2.61	(n=9)
	Alliance B	4.44	(n=6)	5.43	(n=14)
June 1998	Melbourne	3.04	(n=31)	4.52	(n=47)
	Sydney	2.59	(n=30)	3.44	(n=38)
	Canberra	4.38	(n=10)	3.01	(n=10)
	Perth	4.88	(n=6)	4.50	(n=14)
	Alliance A	3.35	(n=25)	1.80	(n=2)
	Alliance B	3.84	(n=6)	5.42	(n=14)
October 1998	Melbourne	3.60	(n=28)	4.71	(n=45)
	Sydney	2.62	(n=33)	3.09	(n=44)
	Canberra	2.58	(n=9)	2.86	(n=13)
	Perth	5.84	(n=6)	5.02	(n=14)
	Alliance A	3.54	(n=18)	4.95	(n=4)
	Alliance B	3.36	(n=6)	4.52	(n=14)
s.e.d.		1.150			
P		<0.001			

3.4.2 Cooking Loss

Season and place of purchase significantly influenced cooking loss (Table 6).

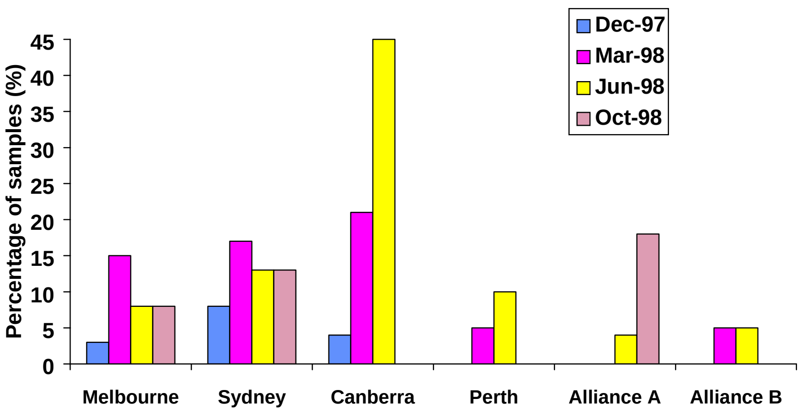
Table 6: Effect of purchasing lamb from retail outlets in Melbourne, Sydney, Canberra and Perth or from retail outlets associated with Branded Lamb Alliance A and B on cooking loss (%) of lamb (M. longissimus lumborum).

	Cooking loss (%)			
	Dec-97	Mar-98	Jun-98	Oct-98
Melbourne	36.9	36.5	36.6	36.0
Sydney	35.5	35.7	35.6	35.9
Canberra	36.3	34.0	35.7	34.1
Perth	35.9	36.4	36.1	36.2
Alliance A	36.1	33.8	35.7	35.1
Alliance B	36.8	36.4	36.4	36.6
s.e.d.	0.528			
P	<0.001			

3.4.3 Muscle pH

Lamb midloins purchased from retail outlets in Canberra were found to have a high percentage of samples with muscle pH greater than 5.8 in the June 1998 audit (Figure 10). It may be suggested that the high proportion of high pH lamb purchased in Canberra at this time may have been due to seasonal influences (eg. winter) or the supply of older, carryover lambs for slaughter. As no background information was obtained from retailers when midloins were purchased, it is not possible to more definitively determine those factor(s) contributing to this problem of high pH lamb.

Figure 10: Proportion of lamb midloins purchased in Melbourne, Sydney, Canberra, Perth, Alliance A and Alliance B recording muscle pH > 5.8 in December 1997 and March, June and October 1998



Although high WB shear force values were obtained for lamb midloins purchased from retail outlets in Perth and also for Alliance B, as previously discussed, very few midloins purchased in Perth and Alliance B recorded muscle pH greater than 5.8.

In addition, muscle pH of lamb was not influenced by season, place of purchase and type of retail outlet (Table 7).

Table 7: Effect of season, place of purchase and type of retail outlet on average muscle pH of lamb midloins (M. longissimus lumborum)

Month	**City**	**Muscle pH**			
		Retail Butcher		**Supermarket**	
December 1997	Melbourne	5.51	(n=31)	5.53	(n=45)
	Sydney	5.63	(n=30)	5.59	(n=33)
	Canberra	5.68	(n=9)	5.61	(n=10)
	Perth	5.61	(n=6)	5.56	(n=14)
	Alliance A	5.60	(n=10)	5.65	(n=12)
	Alliance B	5.47	(n=6)	5.56	(n=14)
March 1998	Melbourne	5.64	(n=30)	5.69	(n=45)
	Sydney	5.68	(n=28)	5.71	(n=37)
	Canberra	5.73	(n=11)	5.69	(n=14)

Month	City	Muscle pH			
		Retail Butcher		Supermarket	
	Perth	5.57	(n=6)	5.61	(n=14)
	Alliance A	5.56	(n=8)	5.55	(n=9)
	Alliance B	5.51	(n=6)	5.60	(n=14)
June 1998	Melbourne	5.47	(n=31)	5.49	(n=47)
	Sydney	5.67	(n=30)	5.68	(n=38)
	Canberra	5.73	(n=10)	5.87	(n=10)
	Perth	5.64	(n=6)	5.66	(n=14)
	Alliance A	5.71	(n=25)	5.67	(n=2)
	Alliance B	5.66	(n=6)	5.62	(n=14)
October 1998	Melbourne	5.61	(n=28)	5.64	(n=45)
	Sydney	5.64	(n=33)	5.66	(n=44)
	Canberra	5.66	(n=9)	5.63	(n=13)
	Perth	5.56	(n=6)	5.58	(n=14)
	Alliance A	5.66	(n=18)	5.54	(n=4)
	Alliance B	5.54	(n=6)	5.63	(n=14)
s.e.d.		0.113			
P		n.s.			

3.5 Conclusions

From the four audits conducted as part of this benchmarking study, it was identified that:

(a) Lamb available to consumers is variable in eating quality, at least when measured objectively using the WB shear force blade.

(b) Average WB shear force values of lamb were not significantly influenced by season.

(c) Inconsistency in tenderness of lamb was identified in lamb purchased in Melbourne, Sydney, Canberra, and Perth and in Alliances A and B.

Importantly, these results indicate that lamb sourced through alliances may not necessarily meet consumer expectations of high eating quality.

Lamb purchased through retail butchers was found to be less variable in tenderness compared with lamb purchased in supermarkets.

Pre- and/or post-slaughter factor(s) contributing to variability in tenderness of lamb identified in this study are not clear.

SECTION 3:

4. IMPLICATIONS AND RECOMMENDATIONS.

This project assessed the variability in tenderness and muscle pH of lamb at the retail level in four Australian capital cities and lamb produced and marketed through two Branded Lamb Alliances. The results of the four audits conducted in this project identified that lamb, on average, was of acceptable tenderness. In this study, average WB shear force values for lamb ranged from 3.49 kg in December 1997 to 3.72 kg in June 1998, with 20% of lamb purchased recording WB shear force values greater than 5 kg. If a cut-off WB shear force value of 6 kg is used, 10% of all lamb purchased in this study had WB shear force values exceeding 6 kg. Lamb was variable in tenderness, irrespective of season, place of purchase or generic or alliance status, at least when tenderness was objectively measured using a Warner-Bratzler Shear Force Blade fitted to an Instron Universal Testing Machine.

This study identified that lamb produced and marketed through an alliance was not any more consistent in eating quality compared with lamb produced and marketed through traditional or 'generic' channels based on WB shear force values. Consumer taste panels were not used to assess lamb in this study, therefore it is not clear whether consumers would be able to differentiate between lamb sourced from alliance or generic outlets. It would be desirable to be able to objectively assess the sensitivity of Australian consumers to different levels of tenderness and define the thresholds at which the majority find the product either highly acceptable, acceptable or unacceptable for tenderness. As tenderness is the key determinant of eating quality, the ability of consumers to be able to differentiate between lamb of differing tenderness levels needs to be demonstrated before a voluntary Meat Standards Australia (MSA) program for lamb is successfully introduced into the Australian lamb industry.

Further work is also required to define those critical control points along the lamb marketing chain that have a major influence on lamb eating quality. Initially, knowledge of the contribution that each key component of the lamb marketing chain makes to the variability in eating quality of lamb needs to be obtained. This has been achieved in the beef MSA program where management practices, critical control points and individual pathways have been set in order for beef to be included in the program and be graded as 3, 4 or 5 star product. Previous research on lamb eating quality has already identified a number of these best practice procedures for lamb production and marketing, however industry has been slow to implement them. For example, the Australian lamb industry generally does not electrical stimulate lamb carcasses, routinely age lamb products at the retail level or tenderstretch lamb carcasses which are all proven technologies used by overseas competitors. It is also suggested that further work be undertaken to include determining the suitability of on-line technology (eg. NIR) as an objective measurement of eating quality of lamb, rather than the use of WB shear force values.

The results of this study are very encouraging for the Australian lamb industry as the majority of lamb achieved an acceptable level of tenderness (based on WB shear force values). However, in this increasingly discerning marketing environment, the industry can not afford to be complacent and it is recommended that pro-active steps be taken to overcome the unacceptable variability in tenderness as identified in this study.

5. DETAILED DESCRIPTION OF INTELLECTUAL PROPERTY

This project did not generate any specific intellectual property or project income. The findings from this project will be communicated to industry with permission from Meat and Livestock Australia.

6. TOTAL FUNDS

(a) Contribution of the MLA to Agriculture Victoria

	Salaries	Travel	Operating	Capital	TOTAL
01/12/97			8,000		8,000
01/03/98			8,000		8,000
01/06/98			8,000		8,000
01/09/98			8,000		8,000
01/12/98			3,300		3,300
TOTAL			35,300		35,300

(b) Contribution of the MLA to NSW Agriculture

	Salaries	Travel	Operating	Capital	TOTAL
01/12/97			6,000		6,000
01/03/98			6,000		6,000
01/06/98			6,000		6,000
01/09/98			6,000		6,000
01/12/98			2,700		2,700
TOTAL			26,700		26,700

(c) Contribution of DNRE

	Salaries	Travel	Operating	Capital	TOTAL
01/12/97					
01/03/98					
01/06/98					
01/09/98	15,496				15,496
01/12/98					
TOTAL	15,496				15,496

(d) **Total funds contributed to project (DNRE + MLA)**

	Salaries	Travel	Operating	Capital	TOTAL
01/12/97			14,000		14,000
01/03/98			14,000		14,000
01/06/98			14,000		14,000
01/09/98	15,496		14,000		29,496
01/12/98			6,000		6,000
TOTAL	15,496		62,000		77,496

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Appendix 1

Appendix 2

Figure 1: Effect of purchasing lamb in December 1997, March, June and October 1998 on WB shear force values (kg) of lamb midloins (M. longissimus lumborum).

Figure 2: Effect of purchasing lamb from retail outlets in Alliance A, Alliance B, Canberra, Melbourne, Perth and Sydney on WB shear force values (kg) of lamb midloins (M. longissimus lumborum).

Figure 3: Effect of purchasing lamb from generic or alliance retail outlets on WB shear force values (kg) of lamb midloins (M. longissimus lumborum).

Figure 9: Effect of purchasing lamb from retail butchers or supermarkets on WB shear force values (kg) of lamb midloins (M. longissimus lumborum).

Appendix 1

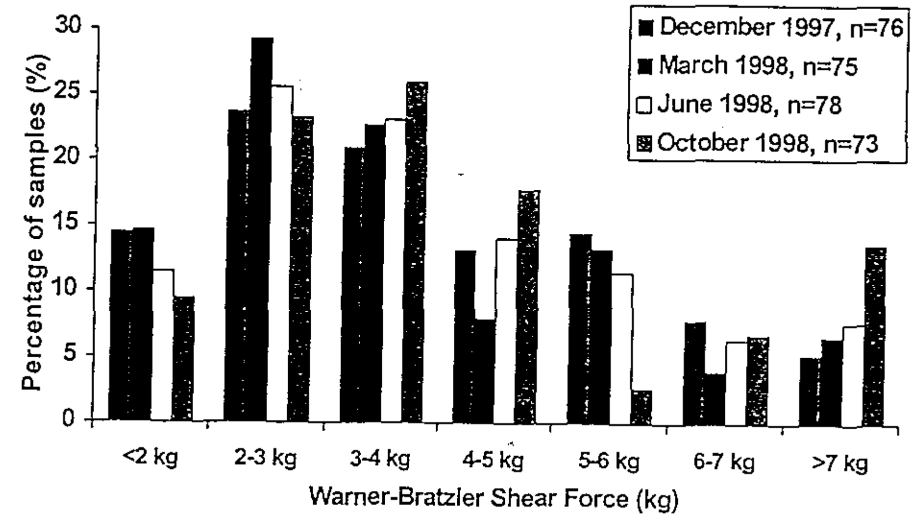


Figure i: Range in WB shear force values of lamb loins purchased in Melbourne in December 1997 and March, June and October 1998

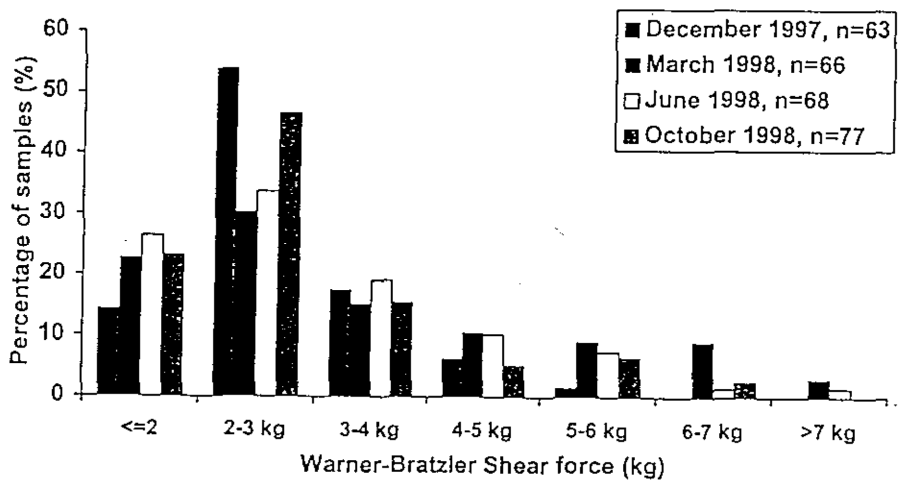


Figure ii: Range in WB shear force values of lamb loins purchased in Sydney in December 1997 and March, June and October 1998

Figure iii: Range in WB shear force values of lamb loins purchased in Canberra in December 1997 and March, June and October 1998

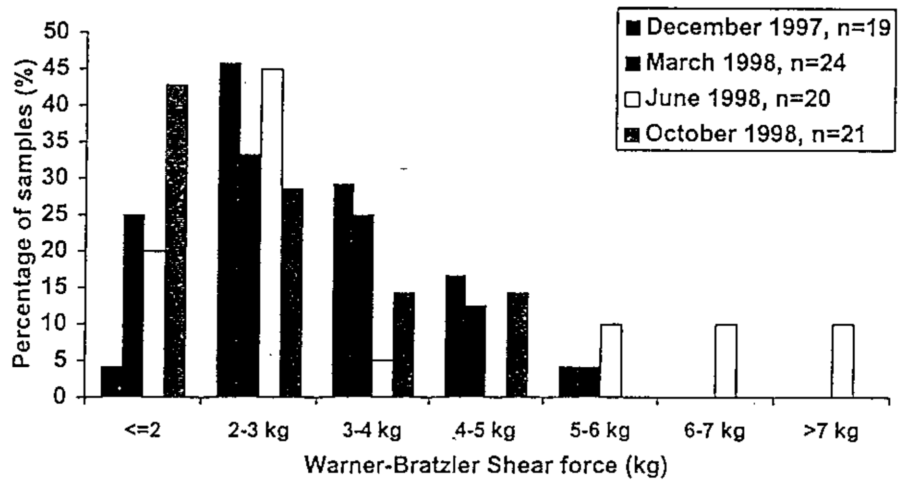


Figure iv: Range in WB shear force values of lamb loins purchased in Perth in December 1997 and March, June and October 1998

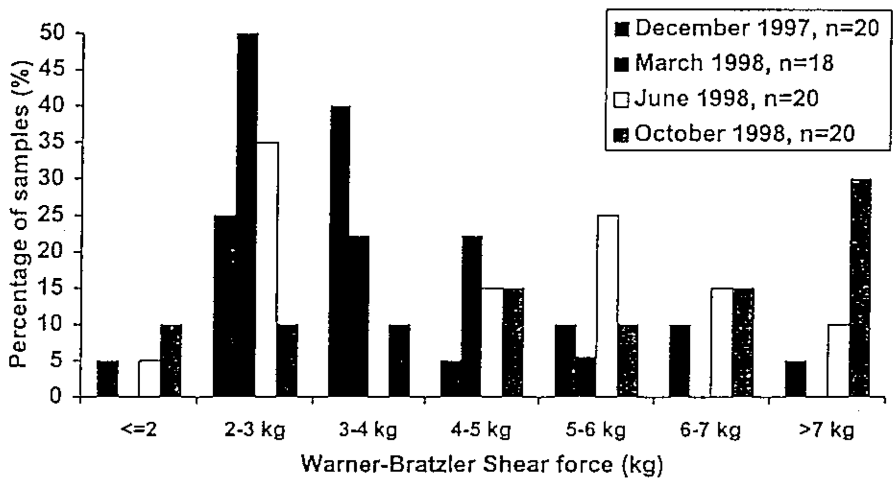


Figure v: Range in WB shear force values of lamb loins purchased in Alliance A in December 1997 and March, June and October 1998

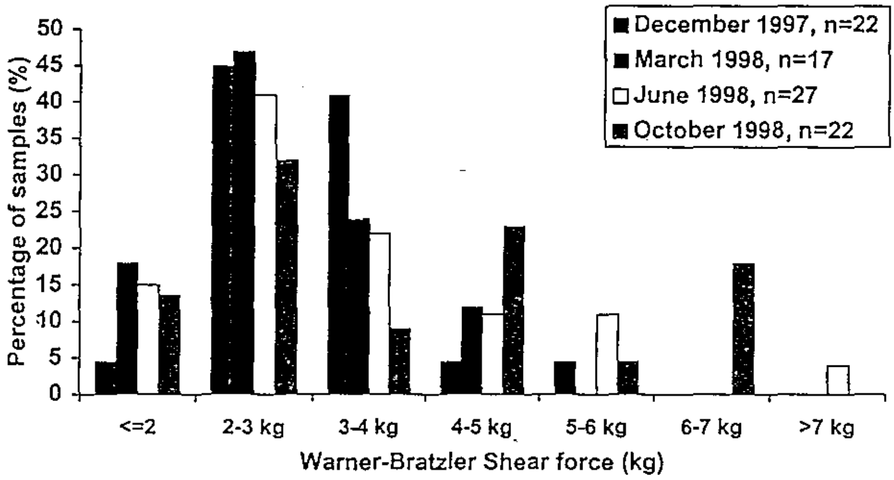
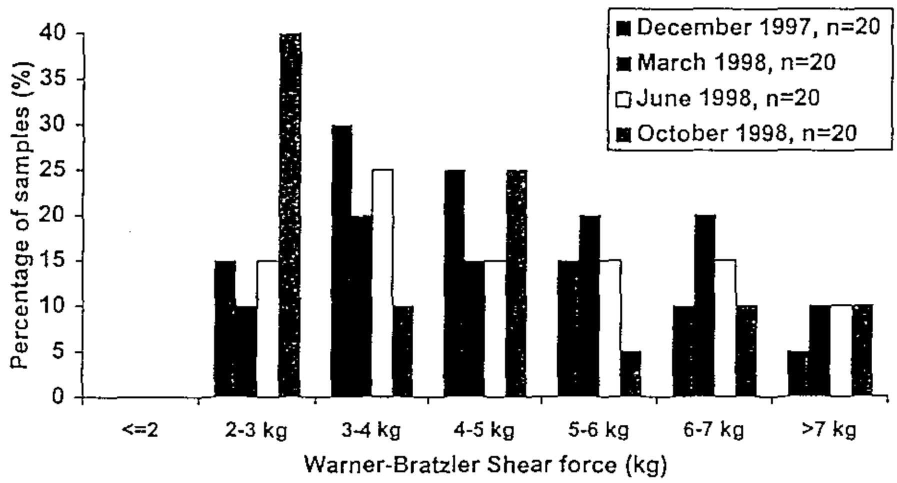


Figure vi: Range in WB shear force values of lamb loins purchased in Alliance B in December 1997 and March, June and October 1998



Improving consistency of lamb eating quality

INCREASING consumer demand for lean meat products has focussed the Australian prime lamb industry toward implementing production systems to supply lambs that satisfy these requirements. Producers have the tools to reduce unnecessary fat and this is most economically achieved through genetic and/or nutritional management.

Delivering lamb of consistent eating quality to consumers is less clear cut.

This is principally due to the lack of feedback to retailers, processors and producers through the lamb marketing chain with regard to their actual meat quality attributes.

Such difficulties could be overcome if a quality assurance system was in place that recognised and rewarded those lambs that were consistently tender.

In this article, on-farm factors, including age at slaughter and nutritional management, which can influence tenderness and meat colour of lamb will be discussed.

Details of current industry initiatives focussed on improving the consistency of lamb eating quality will also be outlined.

The lamb quality characteristics of tenderness, juiciness and flavour are used to describe the eating quality attributes of fresh lamb by consumers.

Of these, tenderness is considered the most important quality characteristic of lamb.

Tenderness is dependent upon a number of biological factors including age, nutritional management and sex of the animal, pre-slaughter handling and post-slaughter management factors, including chilling temperature, electrical stimulation and length of carcass ageing.

The categorisation of 'lamb' includes all animals with no permanent incisors.

In effect, this means sucker lambs of five months of age with no growth checks and carryover lambs of twelve months of age which have experienced nutritional setbacks can both be marketed and traded as lamb. This issue alone may be contributing to inconsistency in eating quality of lamb.

Considerable attention is currently being directed toward the issue of mutton substitution for lamb and the usefulness of a branding system based on dentition to differentiate between lamb and mutton carcasses.

Animal age is not a reliable predictor of eating quality. ►

Both negative and positive relationships between tenderness and age at slaughter have been identified in scientific literature.

In studies where meat from older animals has been shown to be more tender, this has been attributed to older animals having higher subcutaneous and/or intramuscular fat levels which acts to reduce muscle chilling rates post-slaughter (thus minimising risks of cold-shortening) compared with younger animals.

Fast cooling of lamb carcasses post-slaughter can cause cold shortening, which results from a rapid decline in muscle temperature (less than 15°C) whilst muscle pH remains above 6.0.

If precautions are taken to minimise risks of cold-shortening, age effects on tenderness may not be of practical significance in commercial meat producing systems where lambs are well grown and reasonably young at slaughter.

Plane of nutrition before slaughter also has some important implications for meat quality of lamb. Lambs grown on higher planes of nutrition are younger than lambs finished on a lower nutritional plane if slaughtered at the same level of fatness or carcass weight.

Collagen in meat from lambs on a high level of nutrition may also be more soluble than that from lambs on lower planes of nutrition as collagen is synthesised at a higher rate, increasing the proportion of immature collagen present in the meat.

The conventional explanation for tougher meat from older animals is that there is a change in connective tissue structure.

With increasing maturity, the total connective tissue content of muscles remains static but it becomes heat-stable.

Collagen fibres increase in size as the animal grows and the cross-linking of the collagen becomes more complex.

The colour of fresh lamb is an important quality attribute as the physical appearance of a retail cut can influence purchasing decisions of consumers.

Many consumers relate the colour of lean meat to freshness – relying on colour as a criterion of quality.

For example, lamb of a light bright red colour may be considered to be youthful, high quality meat. Meat colour is determined mainly by the concentration and form of the pigment, myoglobin, present within the muscle.

Differences in the concentration of muscle myoglobin account for colour differences between muscles within an animal and for animals of different ages.

Muscle colour intensity increases with increasing age of an animal due to higher concentrations of myoglobin and haemoglobin in muscles.

Meat colour can also be influenced by both pre- and post-slaughter management of lambs and carcasses resulting in meat quality defects, including that of 'dark-cutting'.

> *"Stress immediately prior to slaughter due to transport, mustering or nutrition has important consequences for meat quality, since lambs will not have time to restore muscle glycogen levels before slaughter."*

Dark cutting is a direct consequence of low muscle glycogen at slaughter and is caused by a lack of normal acidification of meat during rigor development.

During rigor, glycogen is converted to lactic acid, which is responsible for the decline in muscle pH post slaughter.

The pH of living muscle is about 7.0. The ultimate pH (measured at 24 hours post-slaughter) of meat from well-fed, rested lamb is about 5.5. Dark cutting meat is defined as having an ultimate pH greater than 5.8. Meat with ultimate pH values above 6.0 can be quite dark in colour, has reduced keeping qualities and may be tough.

It has been shown that there are seasonal variations in eating quality of lamb, particularly in relation to ultimate pH values, with higher muscle pH values generally recorded during periods when nutrition is limiting growth eg. summer.

This may result in a decline in liveweight gains in lambs.

Poor nutrition influences ultimate pH as a result of depleted muscle glycogen stores.

More importantly, stress immediately prior to slaughter due to transport, mustering or nutrition has important consequences for meat quality, since lambs will not have time to restore muscle glycogen levels before slaughter.

If there is insufficient glycogen in the muscle at slaughter, insufficient lactic acid will be formed post-slaughter to reduce muscle pH to an optimum level of about 5.5. Yarding, selection and loading of animals onto trucks prior to slaughter has also been shown to lower muscle glycogen levels, thereby influencing ultimate pH of lamb.

Therefore, notable differences in meat colour may not always be due to lamb age.

Considerable research has identified that post-slaughter management of lamb carcasses can significantly influence lamb eating quality over and above on-farm effects.

Therefore, the ability of the prime lamb industry to improve the consistency in lamb eating quality will require all sectors of the marketing chain, from producers to retailers, to work together to ensure that best practice systems are adopted.

Current initiatives

Variability in tenderness of lamb at the retail level is currently being measured in a benchmarking study funded by Meat and Livestock Australia through the Lamb Consistency Program Key Program. Lamb midloins, purchased from retail outlets in Melbourne, Sydney, Canberra and Perth, are tested for tenderness and muscle pH.

The need for such a study arose from AMLC research that lamb does not always meet consumer expectations for tenderness.

No studies have been conducted which provide benchmark information about the quality of lamb purchased by consumers across Australia.

Monitoring of lamb eating quality, particularly tenderness, will:

- Provide benchmark information on tenderness of Australian lamb.
- Identify particular factors which may affect lamb eating quality.
- Determine whether meat quality standards or systems such as Palatability Assurance Critical Control Points (PACCP) need to be introduced by the lamb industry to improve consistency of lamb eating quality.

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